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UNITED NATIONS DEVELOPMENT PROGRAMME

WORLD METEOROLOGICAL ORGANIZATION

BRA372/010/

# A PLAN FOR THE COLLECTION AND TRANSMISSION OF HYDROMETEOROLOGICAL DATA IN THE BRASILIAN AMAZON BASIN

BY

ROBERT A. HALLIDAY

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## FOREWORD

The large, sparsely settled Amazon River basin represents an enormous challenge to persons engaged in collection of hydrometeorological data. Environmental conditions are rigorous and site access is difficult and costly thus making it necessary to consider the use of advanced and unconventional data collection procedures. The need for widespread use of telemetry systems was identified in earlier work. This report discusses the various options available and recommends a system for the Brasilian Amazon basin.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| CESP | Centrais Elétricas de São Paulo S.A. - Electrical Power Plants of São Paulo Ltd. |
| CNEC | Consórcio, Nacional de Engenheiros Consultores - Nationale Consortium of Consulting Engineers |
| CNES | Centre Nationale d'Etudes Spatiale - National Centre for Space Studies, France |
| CPRM | Companhia de Pequisas e Recurcos Minerais - Research Company for Mineral Resources |
| DCP | Data Collection Platform |
| DNAEE | Departamento National de Aquas e Energia Electrica du Ministerioria de Aquas e Energia Eléctrica - National Department of Energy and Electrical Power of the Ministry of Water and Electrical Power |
| DHN | Directoria de Hidrografia e Navegação da Marintia - The Hydrographic and Navigation Direction of the Navy |
| DNOS | Departmento National de Obras de Saneamento de Ministerio de Interior - National Department of Sanitary Works of the Ministry of the Interior |
| ELETRONORTE | Centrais Elētricas de Norte de Brasil, S.A. - Electrical Power Plants of Northern Brasil Ltd. |
| ELETROBRAS | Centrais Elētricas Brasileiras, S.A. - Brasilian Electrical Power Plants Ltd. |
| EMBRATEL | Empresa Brasileira de Telecomunicaçoes - Brasilian Telecommunications Company |

| | |
|---|---|
| ERTS | Earth Resources Technology Satellite (now Landsat) |
| ESA | European Space Agency |
| GOES | Geostationary Operational Environmental Satellite (see also SMS) |
| INMET (formerly DNMET) | Instituto Nacional de Meteorlogia de Ministerio da Agricultura - National Institute of Meteorology of the Ministry of Agriculture |
| INPE | Instituto de Pesquinas Espaciàis - Space Research Institute |
| MSS | Multispectral Scanner |
| NASA | National Aeronautics and Space Administration, U.S.A. |
| NESS | National Environmental Satellite Service, U.S.A. |
| NOAA | National Oceanic and Atmospheric Administration, U.S.A. |
| NWS | National Weather Service, U.S.A. |
| PORTOBRAS | Portos de Brasil, S.A. - Brasilian Harbours Ltd. |
| RADAM | Projecto Radar Amazonia - The Amazon Radar Project |
| RBV | Return Beam Videon |
| SAR | Synthetic Aperture Radar |
| SSARR | Streamflow Synthesis and Reservoir Regulation Model |
| SUDAM | Superintendencia de Desenvolvimento da Amazonia - General Directorate of the Amazonia Development |
| TIROS | Television and Infrared Operational Satellite |
| USGS | United States Geological Survey |
| VISSR | Visible/infrared Spin-Scan Radiometer |
| WMO | World Meteorological Organization |

# A PLAN FOR THE COLLECTION AND TRANSMISSION OF HYDROMETEOROLOGICAL DATA IN THE BRASILIAN AMAZON BASIN

## 1. SUMMARY AND RECOMMENDATIONS

### 1.1 Summary

This report is a follow-on from the report prepared by Professor S.I. Solomon in 1977 in which the use of telemetry was recommended at a large number of proposed hydrometeorological data collection sites in Amazonia. Use of telemetry would provide a means of monitoring the operation of stations in remote areas and also provide data on an immediate or "real-time" basis.

This report is based on the writer's visits to Washington, D.C., January 15 to 19 and to Brasil, January 20 to February 9, 1978. Several technical experts were visited in Washington; others in North America were contacted by telephone. In Brasil the writer visited several agencies and companies and studied some prospective gauging locations in Amazonia.

Six different systems of data telemetry were considered in the study, namely conventional radio, meteor burst, Geostationary Operational Environmental Satellite (GOES) self-timed, GOES interrogate, Tiros-N Argos and Intelsat. The report contains a review of these systems. Four systems were given serious consideration and the GOES self-timed system was selected as most suitable from a technical, cost and management standpoint. The GOES self-timed system could also be implemented at a small number of sites (5 or 10) very quickly as a pilot project.

The report discusses the sensors that could be used with the data collection platforms (DCPs), the platforms themselves, and the data reception and distribution system. Detailed specifications for sensors, DCPs and the receive site are contained in Appendices. There is a good possibility that some sensors can be purchased in Brasil. An implementation plan is contained in the report.

The report also contains some recommendations concerning stream gauging procedures and equipment.

1.2 Recommendations

A hydrometeorologic telemetry system should be implemented as soon as possible using GOES self-timed DCPs. As a first step an interagency agreement between INMET and the USA's National Environmental Satellite Service (NESS) should be signed. WMO could expedite the early signing of the agreement.

INMET is recommended as the lead agency in implementing the telemetry system because of its close ties with the USA's National Weather Service and WMO. Also INMET has a suitable location in Brasilia for operation of the receive site and has established networks in Brasil for distribution of data. Both INMET and DNAEE data banks are in Brasilia thus making this location attractive for data reception.

A pilot project involving a small number of sites should be implemented as soon as the agreement is signed. These pilot stations should be selected on the basis of meeting urgent needs but also one or two sites should be located close to operational centres to provide a means of training staff in the operation and maintenance of telemetry stations.

The equipment for the pilot project should be purchased outside of Brasil, however, in the future, sensors could be purchased in Brasil. A suitable and useful project for INPE would be the design and construction of a GOES DCP.

Float actuated water level sensors should be used where feasible, servomanometers otherwise. Both tipping bucket and storage type rain gauges would be used. All of these sensors are, or could be manufactured in Brasil. Consideration should be given to using data telemetry without on-site recording of data. This would decrease the original investment and future operating costs at each site.

Operating agencies in Amazonia should use the data provided by satellite in scheduling visits to gauging stations. Gauging stations should not be visited by rote but on an "as and when required" basis. The proposed telemetry system has considerable potential for expansion at low cost. Consideration should be given to installing telemetry sites at any location where site access costs are high.

Arrangements should be made for maintenance of all equipment and instrumentation in Brasil. The problems that could arise in sending DCPs to North America for maintenance are enormous. One Brasilian company that could provide this service has been identified.

With regard to stream gauging practises and equipment, it is recommended that conventional stream gauging be carried out on small streams (less than 500 m in width). The use of savonius (Kartan) type current meters is not recommended.

The single most useful procedure for measurement of large streams (greater than 500 m in width) is the moving-boat technique. This provides a simple, rapid and safe method of measuring large streams. The use of anchored boat techniques is not recommended.

In the long term, consideration could be given to the purchase of specially equipped hydrometric vessels for special projects. However the need at this time is not great.

The possibility of using the Soviet method of gauging from aircraft should be investigated.

The possibility of using ultrasonic stream gauging techniques seems very limited, both in terms of the specifications of existing equipment and the lack of sites in Amazonia where the need exists.

Single velocity methods could be useful at a limited number of sites subject to frequent backwater.

The electromagnetic method should not be considered.

## 2. INTRODUCTION

### 2.1 Background

A study in 1977 by Professor S.I. Solomon proposed a significant expansion of the hydrometeorological network in the Brasilian Amazon basin. The necessity of recording and/or telemetering data from many sites was also identified. This report is the result of a follow-on study during which several possible data telemetry systems for use in the Amazon basin were evaluated. The availability of Brasilian sensors was also investigated as were existing and possible stream gauging procedures.

The study is based on extensive discussions with representatives of many organizations involved in hydrometeorological activities in Amazonia plus many technical experts in the U.S.A. and Canada. These persons are listed in Appendix 1 - their kind co-operation is acknowledged with thanks. The study is also based on the writer's visits to some typical sites in the basin. Appendix 2 gives the writer's itinerary. A bibliography listing documents consulted in the course of the study and documents that may prove useful to the project is given in Chapter 11 of this report.

### 2.2 Purpose

The purpose of this report is to present a plan for the establishment of a system for the collection and transmission of hydrological and climatological data in the Brasilian Amazon basin. A schedule for implementation is presented. The report also comments on the existing stream gauging techniques and makes suggestions for the future.

### 2.3 Scope

While this report concerns itself with the situation in Amazonia in 1978 and the technology now available to meet project needs, the plan presented is sufficiently broad in scope to meet hydrometeorological telemetry requirements in Amazonia for the foreseeable future.

## 3. PROBLEM DEFINITION

### 3.1 General

The report by Soloman (1977) describes the development of the hydrometric and meteorological network in the 3 700 000 $km^2$ Brasilian Amazon basin. The networks have been developed fairly recently by several different agencies. By any definition, there are an insufficient number of hydrometric stations.

The cost of operation of the hydrometric network is in the order of US $20,000 to $40,000 per station per year. Soloman has proposed an expansion of the hydrometric network to about 350 to 400 gauging stations, about 100 of which require telemetry of data. It is anticipated that this expanded network can be operated for the same budget as the existing network if unconventional procedures are adopted.

The Amazon basin within Brasil is characterized by generally large rivers having relatively small slopes. (There are some streams with rapids however.) Rivers have a pronounced meander pattern and sandbars are evident in many reaches. Despite these seemingly mobile beds, rating curves are quite stable. As pointed out by Solomon, however, persons operating gauging stations must always take the possibility of backwater from the Amazon into account. Ranges of stage can be large - up to 20 m on the Tocantins, for example. River velocities usually are in the order of 1 to 2 m/s.

## 3.2 Data Requirements

Synoptic meteorological data are now obtained in the basin using manual observations and single side band voice radios. If a system for the automatic collection and transmission of hydrometeorologic data were established, it would be possible to supply many users with hydrometeorological data on an immediate or "real-time" basis, if required. These data could be used in preparation of forecasts and also to monitor the performance of sensors. In view of the high operating costs of gauging stations in Amazonia, this latter capability would prove valuable, since, if sensors are operating normally and if there is no need for a discharge measurement, a trip into the gauging station could be cancelled or postponed.

A large proportion of the hydrometeorological sites will require only installation of sensors for measurement of water level (stage) or precipitation or both. However, any telemetering system should provide a means of transmitting additional data if and when required. Some possibilities would include wind speed and direction, air temperature and water quality parameters such as water temperature, specific conductance, pH and dissolved oxygen. It is realized that the water quality in Amazon basin is probably the best in the world, therefore only a few water quality sites are necessary to provide benchmark data. The writer has deliberately ignored the telemetry of sediment concentration data since no satisfactory sensors exist at present.*

Solomon's work indicates that the most pressing need is expansion of the hydrometric network, the meteorologic network being relatively more well developed. Also, because of the convectional characteristic of Amazonian precipitation, good hydrometric data would be an index of total precipitation in a basin.

On the basis of discussions with various agencies, it seems reasonable to measure water level to a precision of 10 mm and precipitation to a precision of 0.2 mm. A precision of $1^{o}C$ in measurement of temperatures would be satisfactory.

* Existing "Turbidity" sensors provide results that vary widely depending on the construction of the sensor and on the shape and size of the sediment particles.

In most cases data could be reported once or twice each day, but during certain critical periods or at certain sites a three hourly reporting interval may be required. The accumulation times in the Amazon are sufficiently long that stations do not need to be monitored more frequently. A rate of change of stage of 40 mm/hr would be considered a high rate.

## 4. REVIEW OF HYDROMETEOROLOGICAL TELEMETRY METHODS

### 4.1 General

Information may be carried on any radio frequency by modulating some property of a carrier signal at that frequency. The terms amplitude modulation (am), frequency modulation (fm) and phase modulation (pm) are used to designate three well known techniques. (Single side band is a method used in handling am signals that is almost equivalent to an order of magnitude increase in transmitter power). Each modulation technique has its application and limitations. For example, am is relatively cheap but is very subject to electromagnetic interference.

There are four basic methods that can be used to relay hydrometeorologic data from a remote site to a user. These are a hard wire (either shared or dedicated), conventional radio telemetry, meteor burst telemetry and satellite telemetry. The hard wire approach is so obviously inappropriate for the Amazon that it will not be discussed. The writer also feels that conventional radio telemetry is inappropriate but such a system will be discussed further. There are four satellite systems that could be used, two of which warrant serious consideration. The meteor burst system also should be seriously considered.

## 4.2. Conventional Radio

In its simplest form, a conventional radio telemetry system consists of a radio at a remote site, connected to one or more sensors, and a master station at a central location. The system is designed so that the remote radio transmits data on a timed basis or perhaps on command from the master. Such systems generally operate at hf (high frequency), vhf (very high frequency), uhf (ultra high frequency) or shf (super high frequency i.e. microwave) frequencies.

Systems based on hf are capable of relaying a signal up to 3000 km at relativey low cost. However, even if single side band techniques are used, such systems tend to be unreliable since they are subject to ionospheric disturbances. They are poorly suited to automatic telemetry of data since this adds greatly to equipment cost; even then reliabilities of 50 to 80% are all that can be achieved. There could also be a problem in obtaining frequency clearances in Brasil.

The vhf, uhf and shf frequencies require a "line-of-sight" between the remote and the master stations. Where this is not possible a repeater station is placed on a high point of land between the remote and the master stations. It is possible that, because of level terrain, data could be transmitted about 100 km in the Amazon without repeaters, provided that antennas were above the level of the tree tops. The problem of ionospheric disturbance is substantially reduced at higher frequencies but the cost of repeater stations in Amazonia makes such a system impractical.

As the number of remote sites is increased, the radio system grows in complexity. Several remote stations may feed into one repeater and a number of repeaters may feed into mircowave repeaters. Once this level of complexity is reached, a mini computer should be installed at the master station to poll each remote site and to store the data as they are received.

Factors that argue against the use of conventional radio telemetry are the large numbers of repeaters required, the lack of existing microwave repeaters and the large installation expense. Also, considerable advance planning is required to establishing a radio system or in making changes once a system has been established since extensive link analyses are required. It should be realized also that the remote sites and repeaters tend to consume relatively large amounts of power and that the consequences of a repeater failure could be great. Several remote stations could be knocked out of service by one repeater failure. Since more suitable alternatives exist, conventional radio will not be considered further in this report.

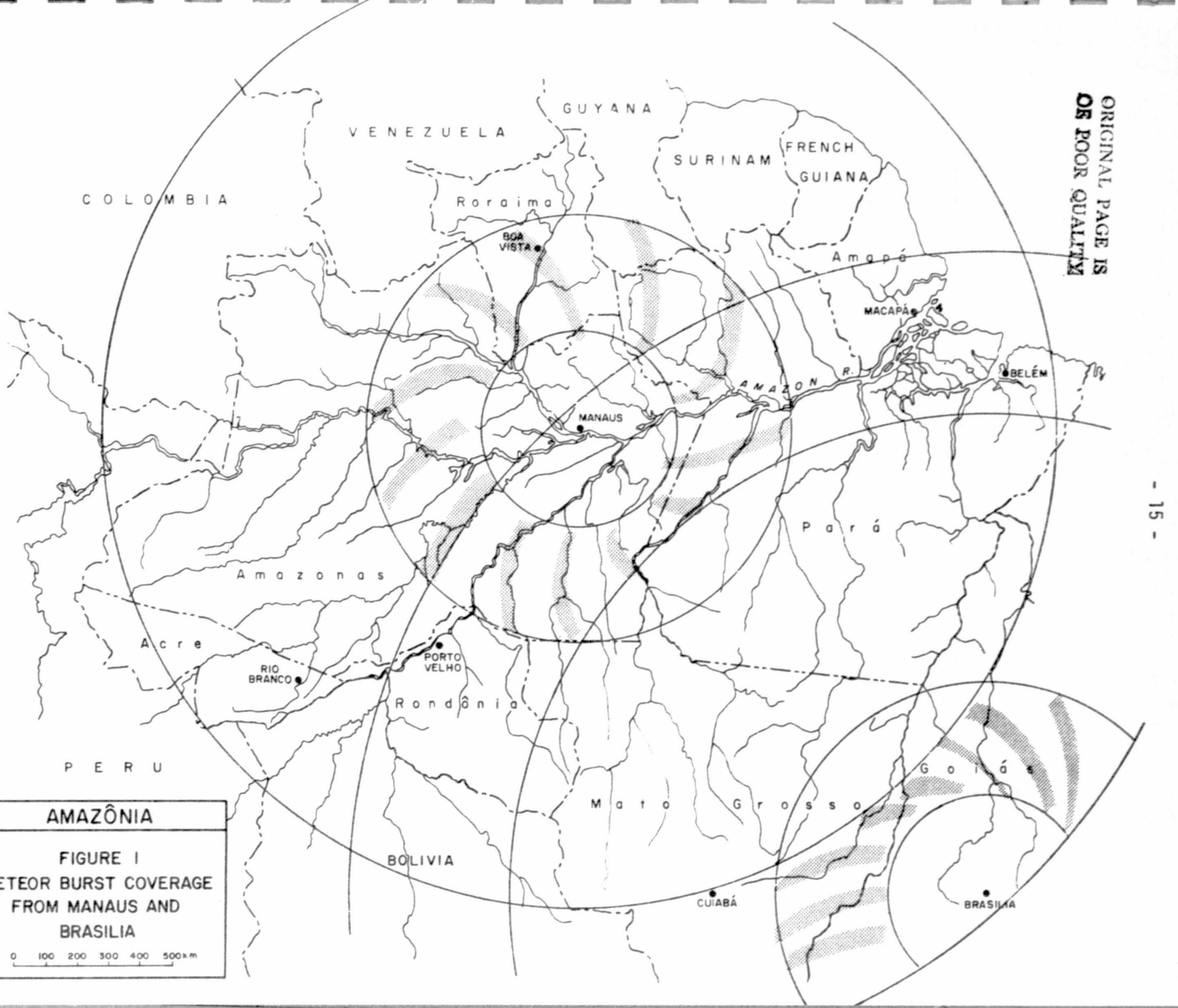
### 4.3 Meteor Burst

Meteor burst telemetry depends on the fact that multitudes of tiny meteorites enter the earth's atmosphere every day leaving trails of ionized particles at an altitude of 80 to 120 km. These trails persist for 4 to 500 ms and may take up an infinite number of orientations. Research into the use of these trails for communications has been conducted by the USA and Canadian military since the 1950s and meteor burst communications systems were used operationaly in the late 1960s and early 1970s by the USA. Essentially the system consists of a technique for reflecting vhf radio signals off of the trails left by micrometeorites.

An American company (Western Union) is now marketing meteor burst communications systems for use in relaying environmental data. What follows is a description of the Western Union system.

A meteor burst communications system consists of a two way radio connected to sensors at a remote site plus an automatic master station that can interrogate the remote station. On command from a mini-computer, the master station transmits the identification number of one or more remote sites. When this command is received, the remote station transmits its data and the master station sends back a code acknowledging receipt of the data. The remote station will then cease to respond to additional probes for a preprogrammed length of time (say 30 minutes). Normally 90% of the stations will respond to a transmit command within one minute and the remaining 10% will take up to 20 minutes.

Successful transmissions will occur for distances up to 300 km then for distances from 650 to 1500 km and occasionally up to 2000 km. Transmissions can also be received in the 300 to 650 km range but with greater difficulty. The master station should be in an area relatively free of electromagnetic interference and should be positioned so that the elevation angle to the horizon is less than $3^{o}$. The antennas of the remote stations should point towards the master station. At least two master stations would be required for coverage of Amazonia. Figure 1 shows the coverage that would be obtained with master stations in Manaus and Brasilia. The shaded areas indicate zones where reception might be more difficult. The meteor burst approach will be considered in this report.




AMAZÔNIA

FIGURE I
METEOR BURST COVERAGE
FROM MANAUS AND
BRASILIA

## 4.4 Landsat

The data collection system that was carried by Landsat-1 (formerly ERTS-1) provided many persons in the hydrologic community with the opportunity to evaluate the use of satellites in telemetering water resources data. The system consists of a small transmitter known as a Data Collection Platform (DCP) connected to sensors at a remote site, a transponder (i.e. repeater) on the satellite and a data reception and distribution facility. Landsat carries a single communications channel which operates on a random access basis. That is, each DCP competes independently for use of the channel. In practice the system can handle up to 1000 DCPs in view at a time without serious interference.

Every 180 s a DCP transmits a message consisting of 64 bits of data (a water level can be encoded in 16 bits) plus a unique identification number. When the satellite is in simultaneous view of a transmitting DCP and a ground station, the message is relayed. (Data can be relayed distances up to 7000 km.) The message can then be distributed to users by the ground station.

The Landsat spacecraft is in a polar orbit. In Brasil data would be received about five times each day during time periods of roughly 06:00 to 12:00 and 18:00 to 24:00. As the satellite may be in view up to 14 minutes, several consecutive transmissions may be received.

Despite its great success and the availability of a ground station at Cuiaba that could be upgraded to receive the data, Landsat will not be considered for the Amazon project. The reason is simply that Landsat is considered to be an experimental program by NASA and thus could be ended at any time. Landsat-3, which was launched on March 5, 1978 carries a data collection system, but Landsat-D, scheduled for launch in 1981, will not.

## 4.5 Geostationary Operational Environmental Satellite (GOES)

Unlike Landsat, GOES is an operational system. (SMS-1 and SMS-2 are NASA prototypes of the GOES spacecraft.) The system consists of two geostationary* satellites positioned 35 000 km above the equator at $75^o$ and $135^o$ west longitude. The GOES spacecraft are USA contributions to a worldwide system of geostationary satellites. Both GOES-west and the European Meteosat (located at $0^o$ longitude) could be used to relay data from parts of Amazonia but the most suitable satellite from a Brasilian point of view is GOES-east which is positioned at the western extremity of the Rio Negro basin.

There are two** methods by which data can be relayed using the GOES spacecraft. The first is an interrogable system in which a DCP consisting of a transmitter and a receiver transmits its data on command from the spacecraft. It would be possible to devise a system whereby data were transmitted once or twice a day during most of the year, then at some much shorter interval, say hourly, during critical times. However, since interrogate commands*** must originate in the United States, the logistics of

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* A geostationary orbit is achieved by injecting a satellite into an orbit directly over the equator at such a position that its orbital speed matches the rate of rotation of the earth on its axis. To an observer on earth the satellite appears to be stationary.

** An experiment is under way in the USA in which a GOES channel is used on a random access basis. If the experiment is a success this would be a very attractive way of telemetering data.

*** As a point of interest, the interrogate command of the GOES spacecraft carries an extremely accurate time code. Companies in the USA have manufactured equipment to receive the commands and give a visual indication of time. This feature could be useful in Brasil in, for example, geodetic surveying or installing certain types of DCPs.

changing the timing of interrogate signals could prove cumbersome.

The second method of relaying data using GOES is through use of ordered self-timed system. In this case each DCP transmits during an assigned time slot (usually 60 s) on an assigned channel. Time slot assignments can range from once hourly to once every 12 hours. Typically transmissions are made every 3 hrs. The self-timed system, while not as flexible as the interrogate system, has the advantage of using DCPs that are about one-half the cost of interrogate DCPs. The interrogate system, however, makes more effective use of the satellite capacity than the self-timed system. About 90% of the GOES DCPs now in service in the USA and Canada are the self-timed type.

Each GOES spacecraft has 183 channels that may be used for data telemetry. One hundred channels are assigned to the interrogate system, 50 to the self-timed and 33 for international oceanographic/atmospheric use. Equipment has been installed in the USA to receive 20 channels from each of the two spacecraft. Capability to receive additional channels will be added as the need arises. If all channels on the satellite were in use, data from over 20,000 DCPs could be relayed. Because the satellites are geostationary, long messages (say 1,000 bits) may be transmitted. The antennas of a GOES DCP must be aimed at the satellite with an accuracy of about $\pm 20^{o}$. In Brasil, the antennas would be aimed almost vertically.

The GOES systems of data telemetry will be considered in this report.

## 4.6 Tiros-N Argos

The Argos data collection system was designed by the French Centre Nationale d'Etudes Spatiales (CNES) and will be carried by Tiros-N, the NASA prototype of a series of operational polar orbiting NOAA satellites. The system, which will become operational in 1978, consists of two satellites in orthogonal polar sun synchronous orbits.

The Argos system is capable of relaying 32 to 256 bits of data several times each day. In Brasil this could take place 6 to 8 times each day. Like Landsat the Argos system operates on a random, self-timed basis but unlike Landsat, the data can be recorded on the satellite and played back when a ground station is in view. The Argos data will be distributed from France, usually with a delay of a few hours. As is the case with other satellite systems, it would be feasible to receive the data directly in Brasil. Tiros-N carries a vhf beacon that may make it possible to construct a relatively low cost receive site.

The Tiros-N system will be considered in this report.

## 4.7 Intelsat

The three satellite systems discussed up to this point all operate at uhf frequencies of about 401 MHz. However, there is a worldwide system of geostationary communications satellites that operate at much higher frequencies (4 GHz) which perhaps could be used for data telemetry. There are two Intelsats located at $24.5^{o}$ and $29.5^{o}$ west longitude that are used by EMBRATEL for both trans-Atlantic and domestic communications.

At present there is an experiment being conducted successfully in the USA and Canada by the U.S. Geological Survey, Comsat General Corporation and Telesat Canada in which the Canadian domestic communications satellite Anik is being used to relay hydrologic data. The Anik satellite operates at similar frequencies to Intelsat therefore it may appear logical to assume that Intelsat could be used to relay Brasilian hydrometeorological data. However there are some technical risks, potential high costs, and possible operational problems involved. Therefore a telemetry system based on Intelsat will not be considered further in this report.

## 5 SELECTION OF TELEMETRY METHOD

### 5.1 General

There were four data telemetry possibilities identified in the previous chapter as being worth considering for use in Brasil. These were: meteor burst, GOES (self-timed and interrogate) and Tiros-N Argos. In evaluating these alternatives, one fundamental assumption has been made. That is, the data relayed by satellite MUST be received directly in Brasil. In the writer's opinion it would be completely unacceptable to have hydrometeorological data from an operational Brasilian system pass through the USA or France. However, such an arrangement could be used on a short term basis to enable rapid implementation of a small number of telemetry stations that could be used for staff training as well as for meeting immediate data needs. Several factors should be considered in selecting a hydrometeorological telemetry system for Amazonia; these can be grouped in three main categories: technical suitability, cost, and management.

## 5.2 Technical Suitability

Essentially this category poses the question, how closely does the system meet the project needs? Several factors should be evaluated.

a) Timeliness - Can the system provide data as often as required? Can the data be made available to all users?

b) Accuracy - Are the transmitted data accurate? Is there a possibility of verifying accuracy? Note that this refers to the accuracy of the telemetry link not sensor accuracy.

c) Reliability - What are the possibilities and the consequences of failures in DCPs, satellites or ground stations?

d) Expandability - How easy is it to add additional remote sites to the network?

e) Technical Risk - Is the system proven or do elements remain to be demonstrated under actual operating conditions? What are the possibilities for catacylsmic failures?

f) Data Distribution - How complex is the data reception and distribution centre? Are data links proven?

## 5.3 Cost

Given that a system is technically suitable, the cost then becomes of great importance. An added factor in the Amazonia project is that one of the aims is to maximize Brasilian content. The greatest opportunity for this is in purchase of sensors. Since all the proposed telemetry systems could use the same sensors, this factor does not have a bearing on the present analysis.

a) Capital and Operating (DCPs) - What is the initial purchase price? How often must maintenance be performed and at what cost?

b) Capital and operating costs (Ground Stations) - What is the initial purchase price of a ground station? What is the annual maintenance cost?

c) Possibility for cost sharing - Are there existing or proposed facilities in Brasil that could be upgraded to handle hydrometeorological data telemetry?

d) Lifetime - How long will purchased equipment last before it becomes necessary to replace it?

5.4 Management

Any telemetry system must be planned, installed, then operated. How easily can this be done and what types of personnel are required?

a) Implementation - What sort of administrative complexities must be overcome to proceed with the system? For example signing of user agreements, obtaining operating licenses.

b) Scheduling - How long does it take to put the system into service once administrative matters are settled?

c) Personnel - What types of personnel are needed to operate the system? Can their services be purchased or must they be "in-house" staff?

### 5.5 Comparison

The four possible methods for hydrometeorological telemetry in Amazonia were compared by assigning points on the basis of a geometric progression. This tends to exaggerate strengths and diminish weaknesses which is fair because all systems could be used. Also, in totalling the figures, technical suitability and cost were assumed to have equal weight while management was assigned a weight of one-half.

The result of this comparison is shown in Table 1. The meteor burst system was arbitrarily assigned a uniform value and all others rated against that value. It can be seen that the GOES self-timed emerges as the most suitable system. Comments on the various factors are discussed in the following paragraphs.

#### 5.5.1 Technical suitability

a) Timeliness - The meteor burst system is the best with GOES-interrogate almost equally good for the Amazon since parameters do not change quickly and therefore in emergencies additional interrogate commands could be arranged. The Argos system is the poorest since the time at which data can be received cannot be controlled by the user.

b) Accuracy - All systems are equally accurate and all provide some means of error checking.

TABLE 1 - COMPARISON OF TELEMETRY SYSTEMS

| | Meteor burst | GOES Interrogate | GOES Self-Timed | Tiros-N Argos |
|---|---|---|---|---|
| I TECHNICAL SUITABILITY (1) | | | | |
| Timeliness | 4 | 4 | 2 | 1 |
| Accuracy | 4 | 4 | 4 | 4 |
| Reliability | 4 | 4 | 8 | 4 |
| Expandability | 4 | 4 | 4 | 4 |
| Technical risk | 4 | 8 | 8 | 2 |
| Data distribution | 4 | 8 | 8 | 4 |
| Total | 24 | 24 | 34 | 19 |
| II COST (1) | | | | |
| Capital/operating (DCPs) | 4 | 2 | 8 | 8 |
| Capital/operating (ground stations) | 4 | 8 | 8 | 2 |
| Cost sharing | 4 | 8 | 8 | 8 |
| Lifetime | 4 | 4 | 8 | 8 |
| Total | 16 | 22 | 32 | 26 |
| III MANAGEMENT (0.5) | | | | |
| Implementation | 4 | 2 | 2 | 2 |
| Scheduling | 4 | 4 | 4 | 2 |
| Personnel | 4 | 4 | 4 | 4 |
| Total | 12 | 10 | 10 | 8 |
| 0.5 (total) | 6 | 5 | 5 | 4 |
| IV GRAND TOTAL POINTS | 46 | 51 | 71 | 49 |

c) Reliability - The GOES self-timed is considered the most reliable since the DCP consists only of a transmitter not a receiver and transmitter as for meteor burst and GOES interrogate. Eventually Argos DCPs could be most reliable since they are the simplest in concept. However, several hundred GOES self-timed transmitters have now been manufactured and this results in improved reliability.

d) Expandability - All systems could undergo a one hundred percent expansion without difficulty or major changes.

e) Technical risk - Both GOES systems have been proven over a number of years of operation. Meteor burst systems are only now being installed and commissioned and the Argos system is yet to be demonstrated. A cataclysmic failure of a meteor burst system would be the failure of a master station, some of the load could be taken by the second station. In the case of the satellite based systems, a cataclysmic failure would be a satellite failure. This would scarcely be noticed with GOES as the system has spare satellites in orbit that can be activated quickly. In the case of Tiros-N failure, the quantity of data received each day would be cut in half.

f) Data distribution - Any hydrometeorological telemetry system for 100 sites implies the use of on line mini-computers to operate the system. In addition the satellite systems require the use of a large antenna installation which can be fixed (and therefore simpler) in the case of GOES or tracking in the case of Tiros-N. Data distribution can be difficult in Brasil but there is an added problem in the case of meteor burst since there is much less scope for flexibility in location of master stations.

5.5.2 Cost

a) Capital/operating (DCPs) - The most expensive DCP is a GOES interrogate DCP, followed by a meteor burst DCP, then Argos, then GOES self-timed. As more Argos DCPs are built their cost should be lower than for a GOES self-timed DCP since they are inherently simpler. Experience in North America has shown that DCPs can operate for many years without maintenance. The meteor burst DCPs now being deployed will be checked by electronics personnel annually. In the writer's opinion this is an unnecessary and costly form of preventive maintenance that could be eliminated once the system is proven.

b) Capital/operating (ground stations) - In all cases, the ground stations form a major part of the cost of the telemetry system. Approximate cost would be U.S. $200,000 for meteor burst (two master stations), $200,000 for GOES (interrogate or self-timed) and $500,000 for Tiros-N. (The cost of a Tiros-N receiver could be reduced significantly if the vhf beacon were received.) A good approximation of the annual operating and maintenance costs would be to assume 10% of the capital cost.

c) Cost sharing - There are really no opportunities for cost sharing in the meteor burst system except that once a system is installed various agencies may wish to add DCPs and therefore assume some share of the operating expenses of the master stations. Since both the GOES and Tiros-N satellites are multipurpose in nature, there is a demand in Brasil for the imagery these spacecraft provide. It appears that both INMET and INPE have plans to install GOES imagery stations; INMET at Brasilia and INPE at S. José dos Campos or Cachoeira Pauliste. INPE is also interested in receiving Tiros-N imagery and Argos data. There is therefore considerable scope for sharing costs of the satellite ground stations but if cost sharing arrangements cannot be made quickly, the data reception station should proceed in any case.

d) Lifetime - The self-timed GOES and the Argos DCPs should last longer than meteor burst or GOES interrogate DCPs since they are simpler. It seems possible that DCPs could be swept away in floods if installations are not sturdy enough or that antennas could be struck by lightning thus destroying a DCP. The writer tends to distrust manufacturer's figures on predicted incidence of failures but the majority of Landsat DCPs installed in Canada in 1972 have operated without failure (except for batteries) since that time and none have been written off as unservicable. It would be reasonable to project a DCP lifetime of at least 5 to 10 years with repairs. Ground station lifetime should be longer.

### 5.5.3 Management

a) Implementation - The meteor burst system would be easiest to implement since all that is required is the signing of a contract with a supplier such as Western Union and the clearing of the meteor burst frequency (about 41 MHz) with the Brasilian Ministry of

Communications. Implementing either GOES system requires the signing of a user agreement with the USA's National Environmental Satellite Service (NESS) while implementing the Argos system requires the signing of a user agreement with CNES. A radio licence would also be required for the GOES or Argos DCPs (401 MHz).

b) Scheduling - Either GOES system could be implemented on a small scale very quickly after administrative matters have been settled. The reason for this is that the GTS line from Washington to Brasilia could be used on an interim basis to receive GOES data for 5 to 10 DCPs although not on a real time basis. Expansion of the system to 100 DCPs requires the installation of a ground station in Brasil. No data could be received by meteor burst until the master stations have been installed, but a meteor burst master station possibly could be installed more quickly than a satellite ground station. The Argos system would take the longest time to implement since the satellite has not been launched and the system tested.

c) Personnel - DCPs can be installed by existing field personnel - a knowledge of electronics is not required. Argos DCPs can be installed most easily, then GOES and then meteor burst. Most of the time would be taken up in installing sensors; the DCP installation can be accomplished by two persons in a few hours. Maintenance of DCPs would be on a field substitution basis - actual repairs could be contracted out. It would be useful if the organization operating the DCPs had some personnel on staff with a fundamental knowledge of electronics in order to make preliminary examinations of faulty DCPs.

Personnel will be required to operate and maintain the minicomputers that will be installed as part of the telemetry system. One person with programming experience will be needed to enter new DCPs into the computer and to make changes in the operating programme. The USA companies that market minicomputers usually provide training as part of the sales agreement but the person taking this training must already have a knowledge of programming. In addition, an electronics engineer with a knowledge of digital systems will be needed to maintain the ground stations. It's possible that this maintenance could be contracted out but it would be preferable to have the person on staff.

# 6 PROPOSED SYSTEM FOR AMAZONIA

## 6.1 General

Chapter five gives the rationale for selecting the GOES self-timed system for collection and transmission of hydrometeorological data in the Brasilian Amaziona basin. The purpose of this chapter is to describe the system while subsequent chapters will give details concerning sensors, DCPs and the ground station. The implementation method is also described.

If it is not possible to reach an agreement for use of the GOES satellite, the only reasonable alternative is meteor burst. A meteor burst system is described in 6.4.

## 6.2 System Description

The system would consist of about 100 DCPs transmitting at intervals of 3, 6, or 12 hours by the GOES east satellite to a ground station located at INMET in Brasilia. Data would be distributed to users using existing INMET circuits. Climatological data would be stored in the INMET data bank while hydrologic data would be separated from the climatological and entered into the data bank at DNAEE, also in Brasilia. This distribution should eventually be carried out automatically by a minicomputer equipped with an auto dialer. In addition there should be two dial-in circuits that could be used by gauging station operators to verify DCP performance, especially at time of installation. These lines should have data rates that are compatible with the switched Brasilian telephone network. It is the writer's understanding that 110 baud is a maximum.

Expandability of the system would be provided by requesting 100-three hour time slots from NESS. As the system is operated it will become apparent that some DCPs could transmit less often - two or more DCPs could then share the same time slot.

There are several ways that reliability of the system can be assured. First, the minicomputer at INMET should be able to store about one week's data, thus giving protection against power and telephone interruptions. Secondly, the DCPs can be equipped with memories that can store (and transmit) several days' data, thus allowing for interruptions due to satellite or ground station problems. When the proposed high speed Intelsat circuit between Washington and Brasilia is in operation, all DCP data could be received in that manner in the event of a major receive site failure. Also if INPE installed a GOES imagery receive site, back-up for the INMET receiver could be provided by installing additional equipment at INPE. Finally, redundancy at key gauging stations could be provided by installing duplicate DCPs and sensors and wiring the system so that each DCP transmits all the sensor data. This "criss-cross redundancy" would protect a site against all failures except complete destruction.

## 6.3 System Implementation

The first step in implementing a GOES hydrometeorological telemetry system for the Amazon is to establish an interagency agreement for use of the satellite. A draft agreement appears as Appendix 3 in this report. The two responsible agencies should be INMET in Brasil and NESS in the USA. This could perhaps be expedited through the good offices of WMO. INMET is recommended as the responsible agency in Brasil for two reasons. First, INMET has close operating relationships with the National Weather Service (NWS) in the USA and NWS co-operation is required in obtaining GOES data prior to construction of the Brasilian receive site. Secondly INMET also has ties with WMO, and WMO could be helpful in establishing the agreement.

As the main thurst of this project is the collection of hydrologic data, INMET must be able to assure DNAEE that all hydrologic data will be forwarded on receipt.

While the GOES agreement is under negotiation, the transmit frequency of the DCPs should be cleared for use anywhere in Amazonia by the Brasilian Ministry of Communications. The 50 self timed channels lie in a band of 401.700996 to 401.774450 MHz.

Also at the same time INMET should proceed with activities for installation of a GOES ground station. A list of companies that could install the ground station is included in Appendix 6 of this report. It would be preferable to construct a single station for receipt of both imagery and DCP data - if not the DCP station should proceed in any case.

Negotiations should also be carried out with suppliers of DCPs but purchase orders should not be issued until the agreement is signed. An order for the initial quantity of DCPs should be placed as soon as the agreement is signed. Sensors could be purchased and installed in advance of the agreement being signed.

A bar chart showing a tentative schedule can be seen in Figure 2.

## 6.4 A Meteorburst Alternative

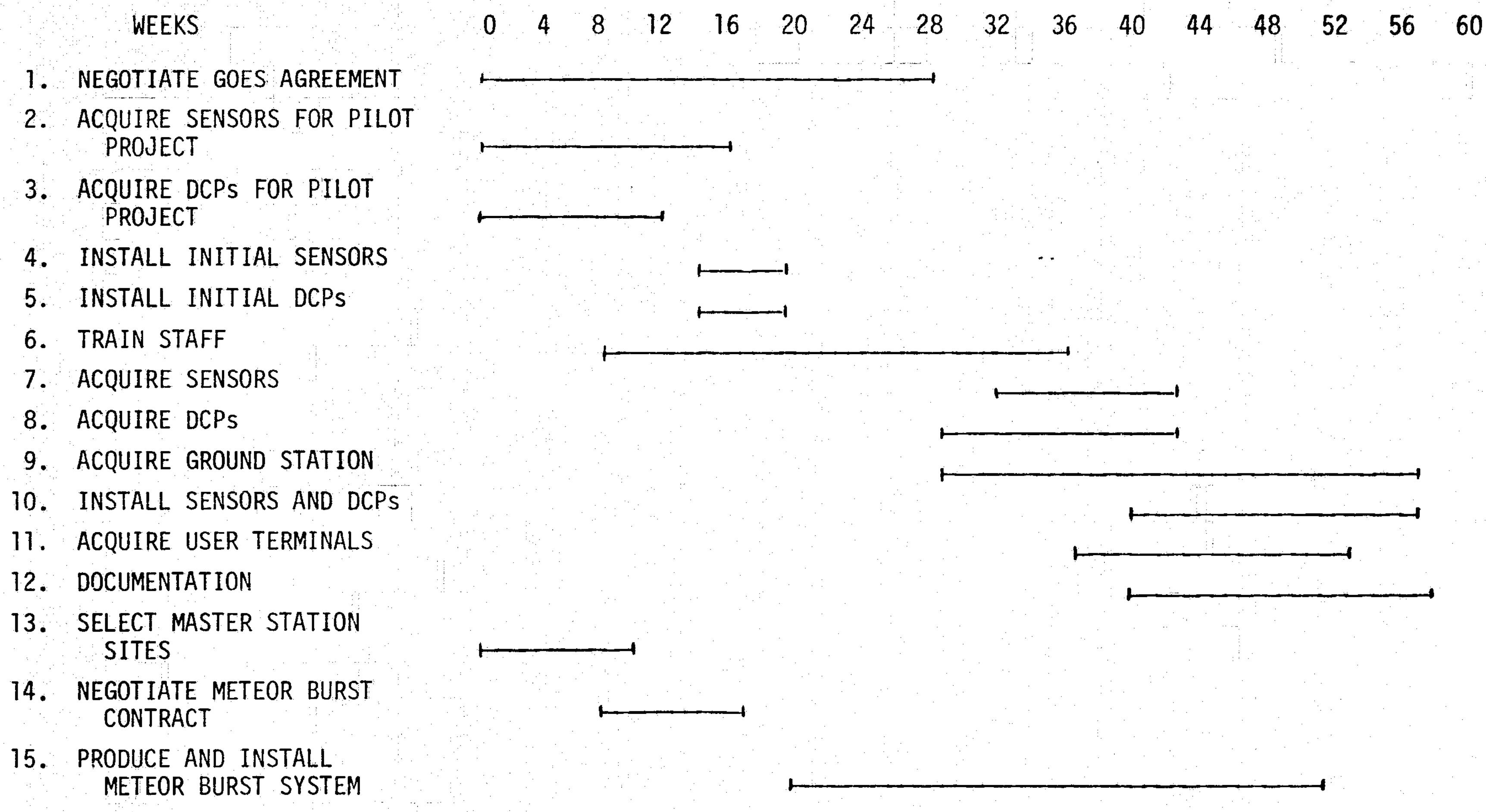
The most difficult problem in implementating a meteorburst system will be that of selecting the sites for the master stations. The size of the Amazon basin and the locations of cities having good telecommunications facilities may mean that coverage of some areas would be difficult.

The most logical site for one master station is Manaus. It would be necessary to select a site on a hill that would provide no more than a $3^{0}$ elevation angle to the horizon in all directions. Also the site would have to be free of electromagnetic noise.

Another master station could be installed at Brasilia but, as can be seen in Figure 1, there will be portions of the basin from which reception could be difficult. Figure 3 shows the situation if the second master station were installed at Porto Velho. There is an improvement, but since there is no microwave service between Manaus and Porto Velho, the two master stations would not be able to interact. Furthermore it would be difficult to send the data from Porto Velho to Brasilia.

As it is important that the two master stations communicate with each other, it would be necessary to use Manaus and Brasilia as the master station sites and accept any

FIGURE 2 - AMAZONIA TELEMETRY PROJECT SCHEDULING
- GOES, ITEMS 1-12
- METEOR BURST, ITEMS 6,7,11,12,13,14,15



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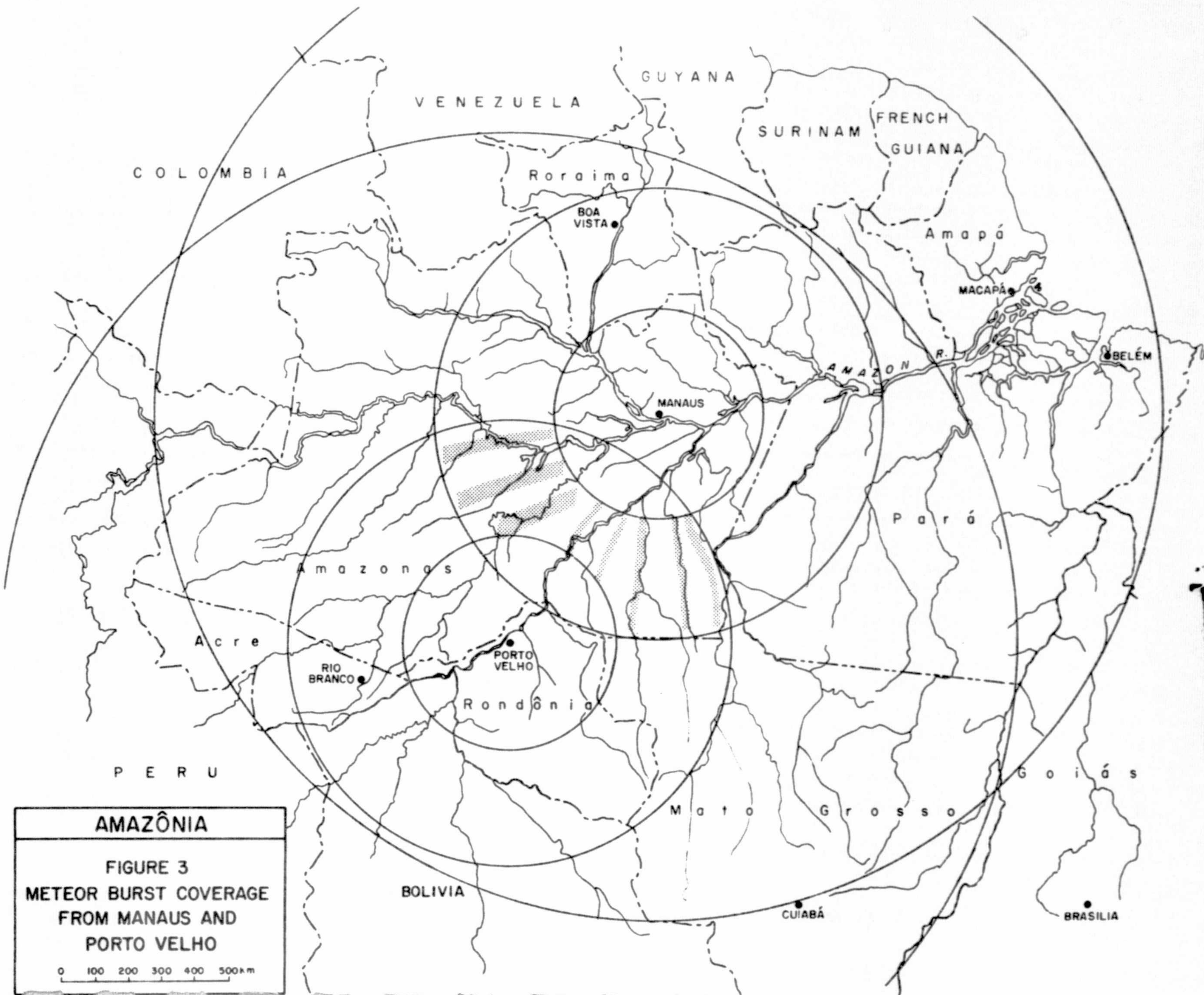


AMAZÔNIA

FIGURE 3
METEOR BURST COVERAGE FROM MANAUS AND PORTO VELHO



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data loss that may occur. Western Union could made a good forecast of the probability of receiving data at all times. One acceptance criterion used in the USA is that 98% of the data should be received from 95% of the sites in one hour. The company should also examine the exact master station sites to ensure that they are free of electromagnetic interferance. The site adjacent to INMET in Brasilia would be satisfactory in the writer's judgement. A company in the USA (Systems Consultants Inc., Oakland, Calif.) has considerable experience in consulting on meteor burst systems and could perhaps represent the project in negotiations with Western Union or any other supplier.

Once master station sites have been selected, a contract should be negotiated for a complete meteor burst system. The specification for DCPs given in Appendix 5 could serve as the basis for the meteor burst DCP specification. It would be preferable to call for a phased installation of DCPs, say 25% installed when the first master station is activated and the remainder to follow within a one year period provided the first units meet specifications. (Western Union personnel would carry out the installation but Brasilian help would be needed in providing site access, clearing sites and installing sensors.)

The data distribution system for meteor burst would be identical to that for GOES.

The main problem in opting for a meteor burst system is that a pilot project is not really possible as a master station must be installed before data can be received. A meteor burst schedule is shown in Figure 2.

# 7 SENSORS

## 7.1 General

There are two parameters that will be transmitted by most of the GOES DCPs. These are stage and rainfall. Other data may include wind speed and direction, air temperature, relative humidity, water temperature, specific conductance, pH and dissolved oxygen. There are many possibilities for purchase of sensors in Brasil, especially the basic ones. The following paragraphs give basic information on sensors; details are contained in Appendix 4. All prices are shown in USA dollars - the writer understands that the project can import instrumentation free of taxes.

It is recommended that the initial order of DCPs be in quantity seven, five for immediate installation and two for spares and for use in staff training.

## 7.2 Stage

There are two basic methods of sensing stage. The first is through the use of a float operating in a stilling well and the second is through measurement of hydrostatic pressure above a fixed point in the streambed, this pressure being proportional to stage (Halliday and Terzi, 1976). The float system is preferred where it is feasible to construct a stilling well. (Some tropical countries have experienced problems with snakes in stilling wells - the Amazonian wells should be constructed so that this possibility is reduced.) Considering the range in stage that can occur in the Amazon streams, it may be very difficult to construct sufficiently strong freestanding stilling wells. Although bridges in the Amazon basin are rare, it may be possible to attach a few stilling wells to piers or abutments at those sites where a gauging station can be established near a bridge or at a harbour or ferry wharf. Because such sites may be subject to increased scour or deposition, maintenance could be more of a problem.

When stilling wells cannot be installed, several pressure systems can be used. Many of these depend on the use of the gas purge technique in which a small quantity of nitrogen is bled into the stream and the back pressure in the system measured using a servomanometer or servo-beam-balance. The writer prefers the servomanometer system. Servomanometers are not available in Brasil and would have to be purchased from Canada or the United States. However, it should be possible for a company such as Hidrologia S.A. to manufacture the servomanometer in the future.

Another type of pressure sensor is now being marketed by Hidrocean Ltda. Essentially this sensor is a temperature compensated differential pressure transducer. The problem with this type of sensor is that its accuracy is a percentage of the maximum range in stage. The Hidrocean sensor would not be accurate enough for ranges in stage in excess of 2 m. There is an additional consideration in that the Hidrocean sensor is about twice the cost of a servomanometer and this sensor must be placed in the river therefore making it subject to loss. An advantage of the Hidrocean sensor is that it can be connected directly to DCP without interface. The servomanometer requires an interface that is a modification of a device manufactured by Hidrologia.

The Hidrologia device is essentially a modified version of the Leupold & Stevens Telemark. It can be connected directly to a DCP provided that one circuit board (which Hidrologia has already designed) is added. The writer proposes that this device be made exactly compatible with the Stevens Memomark, another water level encoder. The Hidrologia device can also be connected directly to a float system.

To start the telemetr' program, it is recommended that a small quantity of servomanometers be purchased outside Brasil and that the Hidrologia or the Stevens encoder be used. For the future, consideration should be given to having the servomanometer manufactured in Brasil and to conducting a test with the Hidrocean sensor, perhaps one having a range of about 5 m or less.

Although Professor Solomon's report recommends the installation of several water level recorders, it could be argued that since water levels of the Amazonia rivers change slowly, a correct stage hydrograph could be reconstructed using only transmitted data (Kite and Reid, 1976). This technique would eliminate the need for recorders at DCP sites. Where recorders are installed, the writer recommends the Stevens Type A recorder. Thousands of these have been operated successfully in all parts of the world. Apparently there have been problems in very humid areas with corrosion of clock springs - for this reason extra springs should be purchased.

## 7.3 Precipitation

Both Hidrologia and Hidrocean manufacture tipping bucket rain gauges that could be used in the telemetry system. The gauges provide a contact closure each time the bucket tips; these can be counted and the count transmitted. Because of the intense rain storms in the Amazon, this count should range from 0000 to 9999 before resetting. A small electronic interface would have to be designed to store the counts for transmittal by the DCP. Both Hidrologia and Hidrocean are capable of this. Some DCP manufacturers would provide this interface as part of the DCP.

A study of the relative catch efficiency of the two gauges should be conducted so that data collected by the gauges can be compared without error.

7.4 Wind Speed and Direction

Data concerning wind speed and direction will be needed from very few sites and therefore it may be appropriate to buy these sensors outside of Brasil. If only wind speed data are required, an existing wind run anemometer manufactured by Hidrologia could be modified to provide this information. At present the revolutions of the anemometer are counted mechanically. An electronic counting system could be added, perhaps using the same magnet and reed switch idea that is used in the Hidrologia rain gauge.

7.5 Air Temperature

The range in air temperatures in Amazonia is rather low (about $30^{\circ}$) and since snowmelt is not a concern in the Brasilian basin, it will be possible to use inexpensive thermistors to measure air temperature. A thermistor that is readily available in Brasil should be selected as a standard for the project and the necessary electronic interface designed. Either Hidrocean or Hidrologia could do this.

7.6 Relative Humidity

The writer was unable to determine if relative humidity sensors that would be be compatible with DCPs were manufactured in Brasil. The task is not an easy one and since few sites are involved, it may be preferable to buy these sensors outside of Brasil.

### 7.7 Water Quality

The same thermistor sensor that is used for air temperature could be water-proofed and used for water temperature. Sensors for specific conductance, pH and dissolved oxygen would have to be purchased outside of Brasil. Since water quality is not a problem in Amazonia, it may be preferable to carry out on-site measurements when field parties visit a station rather than attempting to transmit daily data. Generally it can be said that the reliability of in-situ water quality sensors leave much to be desired. One of the chief purposes in transmitting water quality data in the USA is to monitor sensor performance so that maintainance trips can be scheduled.

### 7.8 Manual Entry System for DCPs

There may be a sufficient number of sites in the basin where data from complex sensors are required in real-time and where a local observer is available, that it would be feasible to develop a manual entry keyboard for a DCP. The observer would set a series of switches thus storing, for example, synoptic weather data in the DCP. The DCP would then transmit these values. Use of such a system could be cheaper than buying expensive and complex sensors outside of Brasil.

## 8 DATA COLLECTION PLATFORMS

### 8.1 General

As stated earlier in this report, GOES DCPs have been manufactured for several years by a number of manufacturers. The technology is well proven so there should be no difficulty in purchasing a suitable DCP for the project. A DCP specification and a list of possible suppliers is given in Appendix 5. The user of a DCP is protected to a great extent by the fact that the transmitter for a GOES DCP must be certified by NESS. This chapter contains a description of a GOES DCP, installation procedures and a comment on power supplies.

8.2 GOES DCP Description

A GOES DCP consists of a small electronics package (0.1 to 0.2 $m^3$ volume, less than 10 kg mass) plus an antenna. The antennas vary from manufacturer to manufacturer. One company supplied a microstrip antenna that was 0.7 m square and less than 10 mm thick; other more conventional antennas consist of a 0.6 m square ground plane with a 1.2 m long helical element, or simply a 1.2 m long element. All antennas have a threaded flange for attachment to standard 2-inch (50 mm) galvanized water pipe. It is the writer's understanding that this pipe is readily available in Brasil. Usually a 3 m coaxial antenna cable is supplied.

As GOES DCPs must transmit at a precise time, it is desirable (and in some types, necessary) to use a start box to program the first transmission of the DCP. In some cases this start box also doubles as a field test set that enables the user to check the performance of the DCP. It usually is necessary to have about one start box for 5 to 10 DCPs.

Electronically DCPs consist of a transmitter board that must be certified by NESS and a digital board that serves as an interface between the sensors and the transmitter. Generally DCPs permit the user to enter up to 64 bits of parallel digital data plus 8 analogue voltage signals, 0 to 5 V range. Some manufacturers supply 700 to 1,000 bits of memory thus enabling a user to collect data from sensors, say hourly, and transmit from memory every three hours. Some DCPs also provide signals for turning sensors on and off, thus reducing power consumption, and reference voltages for analogue sensors.

Initially DCPs for the project must be purchased in North America. However, if INPE could develop a satisfactory DCP and have it certified by NESS, this would be useful in the future.

## 8.3 DCP Installation

The installation of a GOES DCP consists of attaching the antenna to the instrument hut, aiming it at the satellite, connecting the antenna lead to the DCP in the hut, connecting the sensors and starting the DCP.

In the Amazon, it will undoubtedly be necessary to cut down a few trees so that the satellite can be "seen" from the site. As can be seen from Table 2, the line of sight to the satellite will be almost straight up. The antenna mast could be cut, bent and welded to provide the correct elevation angle setting, then rotated to point at the satellite, using a hand compass as reference. (Compass declination must be considered.) Pointing accuracy does not have to be good; the antenna patterns are typically a $40^{o}$ cone. Some users in North America aim the antenna midway between active satellite and the spare (that is at $90^{o}$ rather than $75^{o}$ longitude) so that the DCP can communicate with the spare immediately if there is a failure on the active spacecraft.

## 8.4 DCP Power Supplies

All DCPs now being manufactured call for a power supply of 12.5 VDC ± 10%. There are several batteries that could be used

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TABLE 2

GOES ANTENNA AZIMUTH/ELEVATION ANGLES FOR AMAZONIA

| Δ LONG. | LAT. | AZIMUTH | ELEVATION | Δ LONG. | LAT. | AZIMUTH | ELEVATION |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 90 | 25 | 5N | 260 | 71 |
| 0 | 5S | 0 | 84 | 25 | 0 | 270 | 61 |
| 0 | 10S | 0 | 78 | 25 | 5S | 280 | 60 |
| 0 | 15S | 0 | 72 | 25 | 10S | 290 | 59 |
| | | | | 25 | 15S | 298 | 56 |
| 5 | 0 | 270 | 84 | 30 | 5N | 262 | 54 |
| 5 | 5S | 315 | 82 | 30 | 0 | 270 | 55 |
| 5 | 10S | 332 | 77 | 30 | 5S | 279 | 59 |
| 5 | 15S | 340 | 71 | 30 | 10S | 286 | 56 |
| | | | | 30 | 15S | 293 | 52 |
| 10 | 5N | 245 | 77 | 35 | 5N | 263 | 48 |
| 10 | 0 | 270 | 79 | 35 | 0 | 270 | 49 |
| 10 | 5S | 298 | 77 | 35 | 5S | 277 | 48 |
| 10 | 10S | 315 | 73 | 35 | 10S | 284 | 47 |
| 10 | 15S | 325 | 69 | 35 | 15S | 290 | 46 |
| 15 | 5N | 252 | 71 | 40 | 4N | 264 | 44 |
| 15 | 0 | 270 | 73 | 40 | 0 | 270 | 43 |
| 15 | 5S | 290 | 71 | 40 | 5S | 276 | 44 |
| 15 | 10S | 302 | 69 | 40 | 10S | 282 | 42 |
| 15 | 15S | 315 | 65 | 40 | 15S | 287 | 41 |
| 20 | 5N | 257 | 71 | | | | |
| 20 | 0 | 270 | 67 | | | | |
| 20 | 5S | 284 | 66 | | | | |
| 20 | 10S | 295 | 64 | | | | |
| 20 | 15S | 313 | 61 | | | | |

to provide DCP power but the writer recommends that, where possible, automobile batteries be used. These are relatively cheap, easily available and can be obtained with 40 ampere-hour capacities which is adequate for many months of operation. Where automobile batteries cannot be used, for example, charter aircraft may be reluctant to transport an unsealed battery because of the danger of an acid spill, dry batteries such as alkaline, nickel-cadmium, or sealed lead-acid batteries could be used.

In North America small (1.5 to 3 W) solar chargers are used to keep battery voltages up. The writer heard a rumour that a Sao Paulo company was planning to make solar panels, but was unable to verify it. The chief requirement for a solar charger is that it contain a blocking diode to prevent discharge of the battery during darkness. A voltage regulator is desirable but not essential. Many companies in the USA can provide a satisfactory charger. The writer is most familiar with Solarex products.

This same type of power supply could be used for sensors as well.

One installation problem that can be expected in the Amazon is that of rodents eating the cables. The availability of rodent resistant coatings for electrical cables should be investigated. As an alternative the cables could be inserted in flexible, steel conduit.

After the DCP has been installed, the only task remaining is to check with the receive station to ensure that transmissions are being received at the correct times. This should be done before the installation crew returns to base so that if a second visit is needed the cost will not be great.

As an aid to diagnosing DCP performance a company in the USA makes a cheap, simple radio frequency meter. If the meter probe is held about one metre above the antenna, a reading of signal strength can be obtained and the time of transmission verified.

Once the DCP is operating properly, the only check required is to verify sensor performance and battery voltages. In some cases it may be desirable to transmit battery voltage.

Maintainance of DCPs would be by field substitution; the defective DCP would then be repaired at a depot. It's likely that Hidrocean could provide this service. The company has already established contact with one USA supplier (LaBarge Electronics). Hidrologia would have to hire additional electronics personnel before they could provide DCP maintenance.

# 9 GROUND STATION

## 9.1 General

The proposed location for the ground station is at INMET in Brasilia, but two concepts for the station should be considered. First, a station dedicated to the reception of GOES DCP data and secondly, as a modification to an imagery station. The main difference is the antenna system. The installation of a ground station is sufficiently complex that a contract should be negotiated with a North American company for the entire installation. A specification for a ground station appears in Appendix 6.

## 9.2 Ground Station Description

The ground station will consist of an antenna that receives the signal from the satellite, a preamplifier that amplifies the signal, a receiver that separates the specific GOES channel from all other channels, a demodulator/bit synchronizer that converts the signal to a suitable format for processing, a minicomputer with terminal for processing and display of the data and a telecommunications interface for distribution of data. The antenna should be located on the north side of the INMET building in Basilia, the other equipment can be housed in two standard 19-inch (482.6 mm) equipment racks which could be located in the INMET telecommunications room. About 2 square metres of floor space should be allowed for the terminal.

### 9.2.1 Antenna

It seems to be generally accepted that a 9 m antenna is required to satisfactorily receive GOES imagery - such an antenna including feed, mount and installation could cost $50,000. On the other hand some authorities (for example Exner, 1977) have proposed antennas as small as 3 m in diameter costing about $10,000 for receipt of DCP data. The reasoning used is that, even though GOES is geostationary, it does move slightly with respect to the earth (about $\pm 2^{o}$ north and south, some drift along the equator). A large antenna is more sensitive to these changes in position, thus if the true benefit of the large antenna is to be realized, it should actually be tracking the small movements of the satellite. The selection of antenna should be left to the ground station contractor, however. INMET should consider paying the difference in price between a DCP antenna and an imagery one in anticipation of eventually installing an imagery capability.

### 9.2.2 Preamplifier

The most widely used preamplifiers are those manufactured by Avantek. The cost would be about $1,000. The same preamp can be used for both DCP data and imagery.

### 9.2.3 Receiver

The only company manufacturing a receiver designed for receipt of GOES DCP data is FG Engineering. This receiver has operated well in a Canadian ground station. The cost is about $3,000. Synergetics is now manufacturing a receiver/demodulator that will be undergoing tests in May, 1978.

### 9.2.4 Demodulator

The demodulator presents the most difficult problem in the design of the ground station. The reason is that the demodulator must have sufficient dynamic range to cope with deviations in the DCP signal from the norm. Two companies, Aydin Monitor Systems and Bay Technical Associates could provide demodulators. It is recommended that a simulator also be purchased in order to check out the system in the absence of DCP transmissions. A demodulator with simulator could cost about $8,000.

The ground station contractor should also investigate work with regard to demodulators being carried out under contract to NASA at the US National Space Technology Laboratory (NSTL), Bay St. Louis, Miss. It is NASA's intention to transfer any developments to private industry.

The Synergetics system should also be investigated.

### 9.2.5 Minicomputer

A minicomputer capable of operating the ground station including processing of data every 3 hours from 100 DCPs, storing data for 7 days and disseminating the data to users is required. It is likely that disk rather than diskette drives would be required therefore the cost of the minicomputer with telecommunications interface would be about \$25,000. In order to be compatible with the existing INMET data distribution system, the system should also have a paper tape punch output.

### 9.2.6 Other Ground Station Costs

Miscellaneous materials such as electronic cabinets could add another \$5,000 to the cost of equipment. The main additional cost however will be the software for the minicomputer. Software charges are always difficult to pin down but \$30,000 to \$50,000 seems possible. There will also be costs incurred in assembling, verifying and documenting the system plus purchase of spare parts. In the writer's opinion a total of \$200,000 should be budgeted for the ground station with the expectation that the final cost could be much lower. In fact, one USA company (Synergetics) claims that a complete single channel GOES station could be supplied for under \$50,000.

## 10. STREAM GAUGING PROCEDURES AND EQUIPMENT

### 10.1 General

As has been pointed out by Solomon, the very nature of the Amazon basin demands the use of unconventional data collection practises. However, even if telemetry is widely used as a means of reducing field travel, it will still be necessary to obtain discharge measurements on the Amazonian rivers for the purpose of developing stage discharge relations.

In some cases conventional procedures using up-to-date equipment are possible; in others, it is necessary to consider unconventional procedures in order to obtain discharge measurements safely and effectively. It should be noted that the following remarks are based on the writer's observations of the rivers in Amazonia. No stream gauging operations were actually observed, therefore some of the comments that follow may seem gratuitous. They are made, however, in an attempt to be helpful, and it is hoped, will be accepted in that spirit.

It should be emphasized that for many gauging stations in Brasil, the problem is one of site access not of making the actual discharge measurement. Widespread use of DCPs would at least ensure that no unnecessary visits were made to a site.

## 10.2 Conventional Procedures and Equipment

Although many rivers in Amazonia are large, there are a number of smaller streams where conventional stream gauging procedures and equipment can be used without difficulty. The writer defines a small stream as one that permits the stringing of a tagline without resorting to extraordinary efforts. In actual practise this means a river having a width of less than 400 to 500 m.

Much of the stream gauging in Amazonia must be carried out by boat. Bridges are few and tend to be high above the water surface, presumably to provide clearance for navigation. In the few cases where bridges can be used, it may be necessary to use sounding reels containing long lengths of cable - also care would have to be taken to use air line corrections. Stream gauging cableways could be constructed at some sites but, in the writer's opinion, the benefits of using cableways in Brasil do not outweigh the costs of construction. This leaves boat and tagline measurements as the only realistic alternative for measuring the small Brasilian streams.

All of the equipment required for conventional boat measurements is available in Brasil, much of it from Hidrologia, S.A. One piece of equipment that has been proposed for use in Brasil is the Kartan current meter which uses a savonius-type rotor. These rotors were originally developed for use in oceanographic work as a means of measuring low velocities and prevention of fouling. The writer feels that they should only be used in hydrometric work if rating tank studies can demonstrate their stability and accuracy when used in higher velocities. Their accuracy when held so that the axis of rotation is not vertical should also be demonstrated.

## 10.3 Nonconventional Procedures and Equipment

There are many rivers in Amazonia that are too wide to string a tagline across. (Boat traffic may also prohibit the use of taglines.) It then becomes necessary to establish a cross-section using targets and to somehow position a boat on that cross-section to take velocity observations or to use even more unconventional procedures. Some of these procedures were discussed by Solomon.

### 10.3.1 Methods involving use of boats

One method involves anchoring floats in the river channel to define the measuring points; the location of these points in the cross-sections are defined by survey techniques. The stream gauging boat is attached to the floats while velocity observations are made. This procedure is time-consuming, cumbersome, and, when rivers are deep and velocities relatively high, can be dangerous. The writer has a strong antipathy to any stream gauging procedure that curtails the freedom of movement of a boat especially during flood stage when rivers may carry large quantities of debris.

Another method requires that a boat be held in position on a given spot by a skilled boat operator while velocity observations are made and the boat's position surveyed by using sextants, theodolites or other survey techniques. Depending on the survey technique used, this method can involve considerable preliminary site preparation and is time-consuming.

Another method makes use of a highly manoeuverable boat and electronic distance measuring equipment to determine distance from a fixed point on shore. The boat operator positions himself by observing shore targets and the read-out of the electronic distance measuring equipment. Another person makes velocity observations in the conventional manner. This method is quick but the distance measuring equipment used (Tellurometer MRB 201) is very expensive.

A fourth boat method and the one recommended by the writer is the moving boat method, (Smoot 1969, 1970, Fast 1978). The method requires that a boat traverse the section-line while velocities are measured by a continuously operating current meter, and depths are recorded on an echo sounder. This method, which has already been used on the Amazon, has the advantage that it is quick and reliable and can be used to measure any river with a minimum of preliminary site preparation. The equipment required for the method includes a good quality survey echo sounder such as the Raytheon DE 719 and the moving boat equipment itself. The latter is sold by CAE Aircraft but could easily be manufactured in Brasil by either Hidrologia or Hidrocean. (Hidrocean already makes a form of moving boat equipment but it uses a Kartan current meter.)

A final boat method is one requiring the use of specialized boats such as the US Geological Survey's "Surveyor" or the Canadian Water Resources Branch's "Aquagauger". There are highly manoeuverable craft that carry enough sophisticated equipment to measure streamflow in several ways and to record the results obtained. These type of craft tend to be used in estuaries for measuring unsteady flow and in the writer's opinion would only be needed in Brasil for specialized studies.

10.3.2 Flow measurements from airplanes

This method involves the use of tracers introduced into the stream from an airplane with the streamflow being computed by photogrammetric methods. The writer has no first-hand knowledge of the technique so cannot make a good evaluation of its suitability for Brasilian conditions. Even if a Sudam airplane could be equipped to make the measurements, there could be a problem in time delays between the date of measurement and the date when data are computed. Also, since much of the site access in Amazonia is by boat, it seems more straightforward to use boat methods.

10.3.3 Ultrasonic (acoustic) method

This method would be suitable for sites that are subject to frequent backwater, are relatively narrow (300-500 m), are relatively sediment free and that have commercial power available on one bank of the river. In the writer's limited experience in the project area there are very few sites that meet these criteria. It should be noted that the more inexpensive single path ultrasonic flow meters such as Atlas and Plessey require some insitu calibration by conventional discharge measurements; multi-path total flow systems such as those produced by ORE do not but are more expensive.

10.3.4 Single velocity method

It has been shown (Strilaeff and Bilozor, 1973) that the velocity measured at a single point in some streams can be related to the total flow. This principle can be used to provide flow data at sites that are subject to fequent backwater. The main problem is to find a recording current meter that will operate for extended periods of time in natural streams without fouling. CAE Aircraft does produce a battery powered recording point velocity meter that could be used but the writer thinks that the programmer system would have to be modified considerably to operate reliably in the humid Brasilian environment. ORE is working on a point velocity meter that uses ultrasonic principles. This could prove suitable.

10.3.5 Electromagnetic method

This method (Herschy, 1976) uses the Faraday principle to measure water velocity through a cross-section and also lends itself to flow measurement under backwater conditions. The commercially available devices manufactured by Plessey requires a connection to commercial power and, since they require embedding a coil in the river channel, and are really intended for very small streams. An attempt was made at using this method on a large Canadian river (the Fraser), but with the earth's magnetic field, proved unsuccessful.

10.3.6 Tracer methods

The size of the rivers involved in the project makes the use of any tracer technique that does not involve radioactive tracers or neutron activation analysis almost impossible. The public relations and technical problems in using these methods prohibits their use.

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## APPENDIX 1
## PERSONS CONTACTED

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| COMSAT GENERAL | Robert Bernier | Washington, D.C. |
| DNAEE | Stelio Elleres de Sousa | Belém |
| HIDROCEAN | Eng.º Joao Iuo A. DeSouza | Rua Humboldt, 191<br>Rio de Janeiro, RJ |
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OF POOR QUALITY

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| --- | --- | --- |
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| US Soil Conservation Service | Manes Barton<br>(by telephone) | Portland, Ore. |
| University of Waterloo | S.I. Solomon | Dept. of Civil Engineering<br>Waterloo, Ontario |
| Western Union | Roy R. Atkins<br>Bill Fox | 7916 Westpark Drive<br>McLean, Va. 22101 |

## APPENDIX 2

### Itinerary of R.A. Halliday

| | |
|---|---|
| 1978-01-15 | Ottawa - Toronto - Washington |
| -01-19/20 | Washington - Belém |
| -01-22 | Belém - Brasilia |
| -01-24 | Brasilia - Rio - Sao Paulo |
| -01-25 | Sau Paulo - S. José dos Campos - Sao Paulo |
| -01-27 | Sao Paulo - Duiaba via Campo Grande |
| -01-28 | Cuiaba - Belém vai Porto Velho, Rio Buanco, Manaus, Santerim, Macapa |
| -02-05 | Belém - Manaus |
| -02-06 | Manaus Tefé - Manaus |
| -02-07 | Manaus - Belém via Santerim |
| -02-09 | Belém - Ottawa |

APPENDIX 3

PROPOSED

MEMORANDUM OF AGREEMENT

INTRODUCTION

The National Environmental Satellite Service (NESS), of the National Oceanic and Atmospheric Administration (NOAA), hereinafter referred to as the operator, (the operator of the Synchronous Meteorological Satellite (SMS) and the Geostationary Operational Environmental Satellite (GOES) and the Command and Data Acquisition (CDA) Station) and the Instituto National de Meteorlogia do Ministero da Agricultura (INMET), Brasil, hereinafter referred to as the user (the distributor and user of data collected in Brasil) agree on the "Joint Understanding" below and agree to fulfill the undertakings specified.

I. Name of Program. The program to which this Memorandum applies shall be known as the "National Environmental Satellite Service - Instituto National de Meteorlogia GOES Data Collection System Program".

II. Joint Understanding.

A. To qualify for collection by the GOES, the data from the user's Data Collection Platform must fall within the definition of environmental data. Environmental data are defined as observations and measurements of physical, chemical or biological properties of the oceans, rivers, lakes, solid earth and atmosphere (including space).

B. Authority for the GOES to utilize the radio frequency band 401.7 to 402.1 MHz as an uplink and the radio frequency bank 468.750 to 468.950 MHz as a down link is contained in the Frequency Assignment Subcommittee/Interdepartment Radio Advisory Committee docket numbers 7422556 and 7422589 respectively. Docket number 7422556 grants the operator the authority to make frequency channels available to the user. However, it is understood that the user must obtain authority from appropriate national agencies to transmit on frequency channels, designated by the operator, within the uplink band. The operator will also provide address codes.

C. The operator will not assign a channel to one user for full time use; however, time periods within a channel will be assigned and on a priority basis. Channel(s) assigned will be associated with the GOES-east spacecraft.

D. The operator reserves the right to terminate or suspend the user's participation in this program in the event of spacecraft or ground equipment limitations requiring curtailment or elimination of services.

E. Unless an exception is specified elsewhere in this Memorandum, data collected for users shall be made available from NESS to other interested parties as appropriate.

F. Data Collection Platforms which the user plans to implement as part of the GOES Data Collection System are subject to certification by the operator before deployment.

G. In consultation with the user, the operator will establish the collection times and data lengths for the user's Data Collection Platforms and the schedules and methods for data dissemination.

H. All transmissions from the Data Collection Platforms to the GOES spacecraft will be coordinated with the operator prior to such transmissions.

I. The user shall have the right to operate a passive ground station.

J. The operator shall not be liable for any damage or injury brought about by the supplying of data or use thereof by the user.

III. Specific Undertaking on the Part of INMET

The user shall:

A. Provide the operator a list of user's Data Collection Platforms showing the type (self-timed, interrogate); where each is to be located; and which platforms are equipped with emergency alarm provisions.

B. Provide the operator notification prior to Data Collection Platform relocation.

C. Provide the operator with the data type and message load planned for each Data Collection Platform.

D. Provide the personnel, funds and equipment necessary to carry out the portion of the program at the Data Collection Platform location.

E. Operate and maintain the Data Collection Platforms in conformance with equipment performance standards as specified by the operator in: National Environmental Satellite Service

Specification for Data Collection Platform Radio Set (DCPRS). Specification No. 200.004, January 27, 1975.

F. Provide the personnel, funds and equipment necessary to operate and maintain facilities for receipt of collected data. These responsibilities include the cost of the communication interface at the NESS facility and the means to forward the data to the terminal point designated by the user. The communication interface is specified by the operator in NESS GOES DCS User Interface Manual, November 5, 1976. The user plans to operate a passive ground station in Brasilia, DF - in the interim, data from a small number of DCPs will be received via an existing Global Telecommunication System (GTS) circuit from the National Weather Service in Washington.

G. Provide periodic reports, upon request from the operator, on the present application of the user's DCS data.

## IV. Specific Undertakings on the Part of the National Environmental Satellite Service

NESS shall:

A. Provide and operate the GOES spacecraft and the NESS ground facilities for receiving data collected from the satellite.

B. Provide telemetry reduction sufficient to monitor the user's Data Collection Platforms for meeting system performance standards.

C. Notify the user by the most expeditious means available whenever NESS system monitoring indicates the user's Data

Collection Platform is performing outside system specifications or is inoperative.

D. Assign priorities for participation in the GOES DCS, scheduling purposes, channel assignments and for special DCS data requests according to the following categories in order of priority:

1. Disaster Warning

2. Operational

3. Experimental

E. Notify the user of modifications to the established operational schedule for collecting data from the user's Data Collection Platforms. Notification will be prior to activation of such schedule changes unless the operator must enact schedule modifications to provide services for emergency warnings. Sudden adverse spacecraft conditions may also preclude the operator from providing the user notification prior to schedule changes. In any event, notification will be made as soon as possible.

This Agreement shall enter into force and effect for one year after signature by both parties and if otherwise consistent with applicable authorization and appropriation Acts of Congress, this Agreement shall remain in force and effect unless and until terminated at the election of either the user or the operator provided notification of such termination is in writing and forwarded by one party to the other, not less than 90 days in advance of termination.

| | | | |
|---|---|---|---|
| Director, NESS | Date | Director, INMET | Date |

APPENDIX 4

SENSOR/SENSOR INTERFACE

1. PARAMETER: Stage

2. NAME: Stacom servomanometer $2000

3. MANUFACTURER:

| | |
|---|---|
| CAE Aircraft Ltd.<br>P.O. Box 1700<br>Winnipeg, Manitoba<br>Canada<br>R3C 2Z8 | Scientific Instruments Co. Inc.<br>518 West Cherry Street<br>Milwaukee, Wisc. 53212<br>U.S.A. |

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: Senses water level by measuring pressure above a fixed point in the streambed. A servo-control is used to balance a differential mercury manometer. The instrument output is a shaft rotation, one clockwise rotation being equivalent to 450 mm increase in stage. Standard instrument ranges are 10.5 m and 15 m but larger ranges can be provided on special order.

6. INTERFACE REQUIREMENTS: Cannot be connected directly to a DCP - must use a shaft position encoder.

7. SUPPLIES REQUIRED: Batteries, dry nitrogen, polyethelene tubing - OD 10 mm, ID 3 mm, spare servo-control unit, spare motor.

8. INSTALLATION REQUIREMENTS: Install in a walk-in shelter approximately 1.5 x 1.5 x 2 m high.

9. NOTES: Any unit purchases from North America should have metric tube fittings - check the availability of polyethelene tubing in Brasil. The servo-control unit should be sealed to prevent damage due to humidity.

# APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Stage

2. NAME: Memomark $1200

3. MANUFACTURER: Leopold & Stevens, Inc.
   P.O. Box 688
   Beaverton, Oregon 97005
   U.S.A.

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: The instrument can be actuated by a float to sense water level directly or actuated by a servomanometer to function as a shaft position encoder. In the existing model one clockwise revolution of the input shaft is equivalent to a 375 mm decrease in stage; the direction of rotation should be reversed for compatibility with a servomanometer. The resolution required is 10 mm.

6. INTERFACE REQUIREMENTS: Cabling only. MS 3106E-28-12S plug is supplied.

7. SUPPLIES REQUIRED: Battery (12 V), lubricants.

8. INSTALLATION REQUIREMENTS: Can be installed on a shelf directly over stilling well or adjacent to a servomanometer. A sprocket and chain assembly having a 15:18 ratio is needed for the servomanometer connection. The unit must be sheltered from rain.

9. NOTES: A wiring diagram is attached.

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## DCP WIRING DIAGRAM

## MEMOMARK AND HYDROLOGIA TELEMARK

| | MS 3102E-28-12P RECEPTACLE | MS 3106E-28-12S PLUG | DCP |
|---|---|---|---|
| .01 | A | A | word 4 first bit |
| .02 | B | B | 4 |
| .04 | C | C | 4 |
| .08 | D | D | 4 last bit |
| .10 | F | F | word 3 first bit |
| .20 | G | G | 3 |
| .40 | H | H | 3 |
| .80 | J | J | 3 last bit |
| common | K | K | logic ground |
| 1.0 | L | L | word 2 first bit |
| 2.0 | M | M | 2 |
| 4.0 | N | N | 2 |
| 8.0 | P | P | 2 last bit |
| 10 | S | S | word 1 first bit |
| 20 | T | T | 1 |
| 40 | U | U | 1 |
| 80 | V | V | 1 last bit |
| | X | X | 12 VDC |
| | Y | Y | Update contact |
| | a | a | -12 VDC |

Note: DCP bit orders are reversed to provide direct ASCII readout.

# APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Stage

2. NAME: Hidrologia telemark

3. MANUFACTURER: Hidrologia S.A.
   Rua Maia de Lacenda, 700
   Rio de Janeiro, RJ
   Brasil

4. LITERATURE AVAILABLE: No

5. DESCRIPTION: The instrument can be actuated by a float to sense water level directly or actuated by, for example, a servomanometer to serve as a shaft position encoder. In the existing model one clockwise revolution of the input shaft is equivalent to a 200 mm increase in stage; it would be preferable, but not essential, if this could be changed to 375 mm to conform to other equipment. The unit should be modified so that four digits of BCD data (resolution 10 mm) are brought out to a type MS 3102E-28-12P receptable in accordance with the Memomark wiring diagram.

6. INTERFACE REQUIREMENTS: Cabling only, connects to MS 3106E-28-12S plug.

7. SUPPLIES REQUIRED: Battery, lubricants, spare motor and switches.

8. INSTALLATION REQUIREMENTS: Can be installed on a shelf directly over stilling well or adjacent to servomanometer as required. A sprocket and chain assembly having a 15:18 ratio is needed for the servomanometer connection. The unit must be sheltered from rain.

9. NOTES: The unit should be protected against humidity as much as possible.

# APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Stage

2. NAME: Linigrafo Hidrocean, Modelo Olimpi - S/03 $5000

3. MANUFACTURER: Hidrocean
   Fua Humboldf, 191
   Bonsucesso
   Rio de Janeiro, RJ
   Brasil

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: The sensor is a temperature compensated capacitive type pressure transducer. The 0 to 5 V output corresponds to full scale. The transducer is anchored to the river bed - a cable transmits electrical signals to shore and provides power. Power input is 24 V. Circuitry should be provided to turn on the sensor only when a reading is required so that power can be conserved.

6. INTERFACE REQUIREMENTS: Can be connected directly to an analogue channel of a DCP - if the DCP has 8 bit analogue output, the maximum range for 10 mm precision is 2.5 mm; if the analogue output is 3 BCD digits, maximum range is about 10 m.

7. SUPPLIES REQUIRED: Two 12 V batteries.

8. INSTALLATION REQUIREMENTS: A sufficiently heavy anchor must be provided. The connecting cable should be rodent proof. The batteries should be housed inside a shelter.

9. NOTES: The sensor should be tested under field conditions to verify its accuracy.

## APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Precipitation

2. NAME: Tipping bucket rain gauge $1000

3. MANUFACTURER:

| Hidrologia, S.A. | Hidrocean |
|---|---|
| Rua Maia de Lacerda, 700 | Rua Humboldt, 191 |
| Rio de Janeiro, RJ | Rio de Janeiro, RJ |
| Brasil | Brasil |

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: Water entering an orifice fills one or two small buckets. The weight of water in the bucket eventually causes it to tip and positions the other bucket for filling. Each time the bucket tips, a switch closure is made. Counting these closures gives a measure of precipitation. Waste water drains out through the bottom of the instrument. In the case of the Hidrologia instrument, each tip is 0.1 mm while for the Hidrocean instrument, each tip is 0.2 mm.

6. INTERFACE REQUIREMENTS: The instrument can be connected directly to a DCP provided the DCP is equipped to count contact closures. Otherwise an interface that converts contact closures to 4 BCD digits is required.

7. SUPPLIES REQUIRED: Spare tipping mechanism.

8. INSTALLATION REQUIREMENTS: The instrument should be securely mounted in a large open space. The wires connecting to the DCP should be protected against rodents. The waste water outlet should be screened to prevent insect intrusion.

9. NOTES: At some sites both manufacturers' gauges should be installed side by side in order to determine relative catch efficiencies.

## APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Air temperature

2. NAME: YSI Linear Thermistor 44212

3. MANUFACTURER: Scientific Division
   Yellow Springs Instrument Co., Inc.
   Yellow Springs, Ohio
   U.S.A. 45387

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: This Thermilinear thermistor network is a composite device consisting of resistors and precise thermistors which produce an output voltage linear with temperature. Accuracy is $\pm 0.1^{o}C$.

6. INTERFACE REQUIREMENTS: A voltage reference source is required. This can be provided by some DCPs but may have to be scaled to the correct value.

7. SUPPLIES REQUIRED: None

8. INSTALLATION REQUIREMENTS: As for any air temperature sensor.

9. NOTES: YSI also produces non-linear sensors (i.e. model 410). These are less expensive but temperature must be calculated by solving a quadratic equation.

# APPENDIX 4

## SENSOR/SENSOR INTERFACE

1. PARAMETER: Air humidity

2. NAME: Lambrecht humidity transmitter

3. MANUFACTURER: Wilh. Lambrecht KG
   D-3400 Göttingen
   Friedländer Weg 65/67
   P.O. Box 76
   West Germany

4. LITERATURE AVAILABLE: Yes

5. DESCRIPTION: Longitudinal changes in a hygroscopic element produced by changes in relative humidity are converted to resistance values. The output is very near to linear especially at high relative humidities.

6. INTERFACE REQUIREMENTS: A reference voltage is required, also the resistance values must be scaled to provide a voltage output of 0 to 5V.

7. SUPPLIES REQUIRED: None

8. INSTALLATION REQUIREMENTS: As for any hygrometer.

9. NOTES:

# APPENDIX 5

## GOES DATA COLLECTION PLATFORM

The data collection platform transmitter must meet or exceed the U.S. National Environmental Satellite Service specifications listed on the attached pages. The platform will be fixed permitting use of a directional antenna.

Electrical specifications

Input voltage 12.5 V ± 10%, reverse polarity protected

Power consumption less than 200 mW average

Data inputs

1. At least 48 bits parallel digital, C-mos compatible: logic "0" - 0 - 1.5 V
   logic "1" - 12 - 1.5 V

2. At least 8 channels analogue, input range 0-5 VDC, output 8 binary bits or 3 BCD digits for each input, overall accuracy ± 0.1%

3. At least 3 contact closure counters, input 5 counts a minute, output 4 BCD digits for each input i.e. 0000 to 9999

Transmitter output

7-bit ASCII numerals

Sensor enables

1. Two switched 12 V output at 1 A at 100 s (approx.) before update

2. Two switched 5 V reference for analogue sensors

Data memory

A memory of about 800-1000 data bits is desirable. Transmissions from memory should be on a first-in, first-out basis.

Antenna

A directional antenna shall be supplied

Mechanical specifications

The platform shall be compact and capable of being backpacked

The weight of the platform should not exceed 20 kg.

The antenna mount supplied shall permit the antenna to be aimed vertically.

The antenna lead shall be 4 m in length.

All mating connectors shall be supplied.

Environmental specifications

| | |
|---|---|
| Temperature | $0^{o}$ - $60^{o}$C |
| Relative humidity | 0 to 100% with condensation (The DCP container shall be purged with dry nitrogen and sealed) |
| Shock, vibration | The DCP shall withstand transportation shock and vibration (non-operating) |
| Rodent protection | All cabling supplied shall be protected against rodents. |

Possible Supplier

American Electronics Laboratories, Inc.
P.O. Box 552
Lansdale, PA. 19446
U.S.A.
Attn: K. Farber

Bristol Aerospace Ltd.
P.O. Box 874
Winnipeg, Manitoba
Canada
R3C 2S4
Attn: B.C. Wiebe

Handar Ltd.
3327 Kifer Road
Santa Clara, Calif. 95051
U.S.A.
Attn: Henry Falleck

LaBarge Inc.
Electronics Division
Suite 910, 1101-17th St., N.W.
Washington, DC 20036
U.S.A.
Attn: G. Conover

The Magnovox Company
1313 Production Road
Fort Wayne, Indiana 64808
U.S.A.
Attn: H.J. Hacker

Estimated price for a suitable DCP - $4000

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Environmental Satellite Service
Washington, D.C. 20233

January 1, 1977
No. S23.006

# DATA COLLECTION PLATFORM RADIO SET

# CERTIFICATION STANDARDS

## (Self-Timed and Interrogated)

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

## SELF-TIMED DCPRS DESIGN REQUIREMENTS

1. RF POWER OUTPUT. The Effective Isotropic Radiated Power (EIRP), of a DCPRS and antenna shall not exceed 50 dBm under any combination of service conditions.

2. FREQUENCY CHARACTERISTICS. The DCPRS transmitted RF shall be in the 401.7 MHz to 401.85 MHz band. See Table 1.

3. STABILITY.

   (a) Temperature. The transmitter carrier frequency shall change by less than 0.5 parts per million over the temperature range of -20°C to +50°C.

   (b) Long Term. The long-term stability (including temperature variations) shall be better than one part per million per year.

   (c) Short Term. The phase jitter on the transmit carrier shall be less than 3 degrees RMS.

4. ELECTROMAGNETIC INTERFERENCE (EMI). All transmitter spurious emissions, when measured with modulation and with antenna and diplexer connected, shall be down from the unmodulated carrier level by 50 dB.

5. TRANSMISSION FORMAT. After a minimum of 4.9 seconds of unmodulated carrier, the carrier shall be modulated with the bit and message synchronization patterns which are at least 2.4 seconds of alternate 1, 0 data bits, and the 46 bit preamble consisting of the 15 bit MLS sync word followed by the 31 bit BCH command word. Maximum duration of this preamble shall be 9.0 seconds. The binary data shall be Manchester encoded eight bit ASCII, odd parity, and shall modulate the carrier in the following manner: a data "0" shall consist of +60° (±5°) carrier phase shift for 5 milliseconds followed by -60° (±5°) carrier phase shift for 5 milliseconds, and a data "1" shall consist of -60° carrier phase shift for 5 milliseconds followed by +60° carrier phase shift for 5 milliseconds. Data rate shall be 100 bps ±0.1 bps. See Figure 1.

6. END OF TRANSMISSION. Immediately after sending the sensor data, the DCPRS shall transmit three (3) eight bit ASCII, odd parity, End of Transmission (EOT) characters contiguously with the ASCII sensor data characters (no break) and return to the standby condition.

7. FAIL SAFE DESIGN. The DCPRS shall incorporate a "fail safe" design feature such that malfunctioning of the equipment shall in no way cause continuous transmission.

8. ANTENNA POLARIZATION. Polarization shall be right-hand circular, according to IEEE Standard 65.34.159.

9. DATA FORMATTING RESTRICTIONS.

The following ASCII control characters must not appear in the DCPRS message: DLE, NAK, SYN, ETB, CAN, GS, RS, SOH, STX, ETX, ENQ, and ACK. EOT characters may only appear at the end of transmission.

10. The DCPRS reporting time shall always be within 30 seconds of it's assigned reporting time.

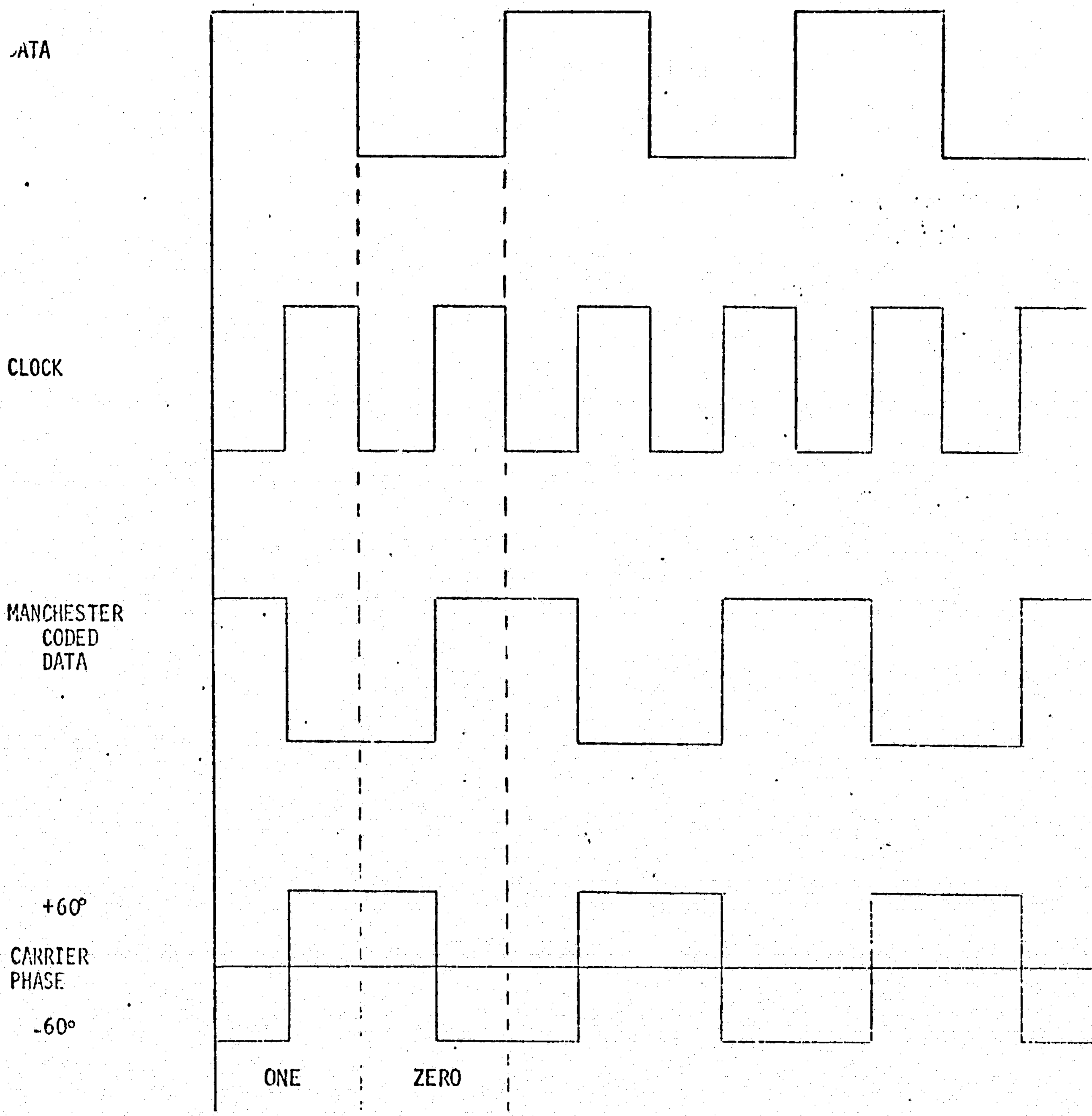
## TABLE 1

### SELF - TIMED DCPRS TRANSMIT FREQUENCIES

| CHANNEL | FREQUENCY | CHANNEL | FREQUENCY |
|---|---|---|---|
| 1 | 401.700996 | 50 | 401.774450 |
| 2 | 401.702495 | 51 | 401.775949 |
| 3 | 401.703994 | 52 | 401.777449 |
| 4 | 401.705493 | 53 | 401.778948 |
| 5 | 401.706992 | 54 | 401.780447 |
| 6 | 401.708491 | 55 | 401.781946 |
| 7 | 401.709990 | 56 | 401.783445 |
| 8 | 401.711489 | 57 | 401.784944 |
| 9 | 401.712989 | 58 | 401.786443 |
| 10 | 401.714488 | 59 | 401.787942 |
| 11 | 401.715987 | 60 | 401.789441 |
| 12 | 401.717486 | 61 | 401.790940 |
| 13 | 401.718985 | 62 | 401.792439 |
| 14 | 401.720484 | 63 | 401.793938 |
| 15 | 401.721983 | 64 | 401.795437 |
| 16 | 401.723482 | 65 | 401.796936 |
| 17 | 401.724981 | 66 | 401.798435 |
| 18 | 401.726480 | 67 | 401.799935 |
| 19 | 401.727979 | 68 | 401.801434 |
| 20 | 401.729478 | 69 | 401.802933 |
| 21 | 401.730977 | 70 | 401.804432 |
| 22 | 401.732476 | 71 | 401.805931 |
| 23 | 401.733976 | 72 | 401.807430 |
| 24 | 401.735475 | 73 | 401.808929 |
| 25 | 401.736974 | 74 | 401.810428 |
| 26 | 401.738473 | 75 | 401.811927 |
| 27 | 401.739972 | 76 | 401.813426 |
| 28 | 401.741471 | 77 | 401.814925 |
| 29 | 401.742970 | 78 | 401.816424 |
| 30 | 401.744469 | 79 | 401.817923 |
| 31 | 401.745968 | 80 | 401.819422 |
| 32 | 401.747467 | 81 | 401.820922 |
| 33 | 401.748966 | 82 | 401.822421 |
| 34 | 401.750465 | 83 | 401.823920 |
| 35 | 401.751964 | 84 | 401.825419 |
| 36 | 401.753463 | 85 | 401.826918 |
| 37 | 401.754962 | 86 | 401.828417 |
| 38 | 401.756462 | 87 | 401.829916 |
| 39 | 401.757961 | 88 | 401.831415 |
| 40 | 401.759460 | 89 | 401.832914 |
| 41 | 401.760959 | 90 | 401.834413 |
| 42 | 401.762458 | 91 | 401.835912 |
| 43 | 401.763957 | 92 | 401.837411 |
| 44 | 401.765456 | 93 | 401.838910 |
| 45 | 401.766955 | 94 | 401.840409 |
| 46 | 401.768454 | 95 | 401.841908 |
| 47 | 401.769953 | 96 | 401.843408 |
| 48 | 401.771452 | 97 | 401.844907 |
| 49 | 401.772951 | 98 | 401.846406 |
| | | 99 | 401.847905 |

FIGURE 1

MODULATION DEFINITION



January 1, 1977

## INTERROGATED DCPRS DESIGN REQUIREMENTS

1. RF Power Output. The Effective Isotropic Radiated Power (EIRP), of a DCPRS and antenna shall not exceed 50dBm under any combination of service conditions.

2. Frequency Characteristics. DCPRS received radio frequency (RF) shall be 468.825 MHz[1]. The transmitter RF shall be in the 401.85 MHz to 402 MHz band. See Table 1.

3. Stability.

   A. Temperature. The transmitter carrier frequency shall change by less than 0.5 parts per million over the temperature range of $-20^{o}C$ to $+50^{o}C$.

   B. Long Term. The long-term stability (including temperature variations) shall be better than one part per million per year.

   C. Short Term. The phase jitter on the transmit carrier shall be less than 3 degrees RMS.

4. Electromagnetic Interference (EMI). All transmitter spurious emissions, when measured with modulation and with antenna and diplexer connected, shall be down from the unmodulated carrier level by 50dB.

5. Transmission Format. After a minimum of 4.9 seconds of unmodulated carrier, the carrier shall be modulated with the bit and message synchronization patterns which are at least 2.4 seconds of alternate 1, 0 data bits, and the 46 bit preamble consisting of the 15 bit MLS sync word followed by the 31 bit BCH command word. Transmission of the address shall be complete within 11 seconds after receipt of an interrogation. The binary data shall be Manchester encoded eight bit ASCII, odd parity, and shall modulate the carrier in the following manner: a data "0" shall consist of $+60^{o}$ ($\pm 5^{o}$) carrier phase shift for 5 milliseconds followed by $-60^{o}$ ($\pm 5^{o}$) carrier phase shift for 5 milliseconds, and a data "1" shall consist of $-60^{o}$ ($\pm 5^{o}$) carrier phase shift for 5 milliseconds followed by $+60^{o}$ ($\pm 5^{o}$) carrier phase shift for 5 milliseconds. Data rate shall be 100 BPS $\pm$.1 BPS. See Figure 1.

6. End of Transmission. Immediately after sending the sensor data, the DCPRS shall transmit three (3) eight bit ASCII, odd parity, End of Transmission (EOT) characters continguously with the ASCII sensor data characters (no break) and return to the standby condition.



---

[1] For the West Satellite. DCPRS assigned to the East Satellite will be required to receive on 468.8375 MHz.

7. Fail Safe Design. The DCPRS shall incorporate a "fail-safe" design feature such that malfunctioning of the equipment shall in no way cause continuous transmission. Further, provision shall be made to retrigger the fail safe via the interrogation link in 90-second intervals without interruption of data transmission by addressing the radio set.

8. Receive Signal. The DCPRS shall continuously receive and demodulate the standard GOES Data Collection System interrogation signal over an input signal level range of -100 dBm maximum to -130 dBm minimum centered at 468.825 MHz[1] and modulated $\pm 60°$PSK with 100 bit/second Manchester coded data. The DCPRS shall be capable of simultaneous reception and transmission and meet all performance requirements of the DCPRS in this mode. The DCPRS shall be capable of automatically locking to the interrogation signal at an input signal level as low as -135 dBm (total signal power with the following data present: 15-bit Maximal Linear Sequence (MLS) sync word (100010011010111) followed by the 31-bit Bose-Chaudhuri-Hocquenghem (BCH) command word (0011010010000101011101100011111)).

9. Acquisition Time. The receiver shall acquire lock on the interrogation signal in 2 minutes or less, from standby condition, when the carrier is within $\pm 100$ Hz of 468.825 MHz[1].

10. Spurious Emissions. Reradiated local oscillator and mixing frequency signals shall be less than 50 microvolts at the antenna or primary power input terminal.

11. Antenna Polarization. Polarization shall be right-hand circular, according to IEEE Standard 65.34.159.

12. DATA FORMATTING RESTRICTIONS.

The following ASCII control characters must not appear in the DCPRS message: DLE, NAK, SYN, ETB, CAN, GS, RS, SOH, STX, ETX, ENQ, AND ACK. EOT characters may only appear at the end of transmission.

---

1 For the West satellite. DCPRS assigned to the East satellite will be required to receive on 468.8375 MHz.

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## TABLE 1

### INTERROGATED DCPRS TRANSMIT FREQUENCIES

| CHANNEL | FREQUENCY | CHANNEL | FREQUENCY |
|---|---|---|---|
| 100 | 401.849569 | 150 | 401.924573 |
| 101 | 401.851069 | 151 | 401.926073 |
| 102 | 401.852569 | 152 | 401.927573 |
| 103 | 401.854069 | 153 | 401.929073 |
| 104 | 401.855569 | 154 | 401.930573 |
| 105 | 401.857069 | 155 | 401.932073 |
| 106 | 401.858569 | 156 | 401.933573 |
| 107 | 401.860070 | 157 | 401.935073 |
| 108 | 401.861570 | 158 | 401.936573 |
| 109 | 401.863070 | 159 | 401.938074 |
| 110 | 401.864570 | 160 | 401.939574 |
| 111 | 401.866070 | 161 | 401.941074 |
| 112 | 401.867570 | 162 | 401.942574 |
| 113 | 401.869070 | 163 | 401.944074 |
| 114 | 401.870570 | 164 | 401.945574 |
| 115 | 401.872070 | 165 | 401.947074 |
| 116 | 401.873570 | 166 | 401.948574 |
| 117 | 401.875070 | 167 | 401.950074 |
| 118 | 401.876570 | 168 | 401.951574 |
| 119 | 401.878070 | 169 | 401.953074 |
| 120 | 401.879571 | 170 | 401.954574 |
| 121 | 401.881071 | 171 | 401.956074 |
| 122 | 401.882571 | 172 | 401.957575 |
| 123 | 401.884071 | 173 | 401.959075 |
| 124 | 401.885571 | 174 | 401.960575 |
| 125 | 401.887071 | 175 | 401.962075 |
| 126 | 401.888571 | 176 | 401.963575 |
| 127 | 401.890071 | 177 | 401.965075 |
| 128 | 401.891571 | 178 | 401.966575 |
| 129 | 401.893071 | 179 | 401.968075 |
| 130 | 401.894571 | 180 | 401.969575 |
| 131 | 401.896071 | 181 | 401.971075 |
| 132 | 401.897571 | 182 | 401.972575 |
| 133 | 401.899072 | 183 | 401.974075 |
| 134 | 401.900572 | 184 | 401.975575 |
| 135 | 401.902072 | 185 | 401.977076 |
| 136 | 401.903572 | 186 | 401.978576 |
| 137 | 401.905072 | 187 | 401.980076 |
| 138 | 401.906572 | 188 | 401.981576 |
| 139 | 401.908072 | 189 | 401.983076 |
| 140 | 401.909572 | 190 | 401.984576 |
| 141 | 401.911072 | 191 | 401.986076 |
| 142 | 401.912572 | 192 | 401.987576 |
| 143 | 401.914072 | 193 | 401.989076 |
| 144 | 401.915572 | 194 | 401.990576 |
| 145 | 401.917072 | 195 | 401.992076 |
| 146 | 401.918573 | 196 | 401.993576 |
| 147 | 401.920073 | 197 | 401.995076 |
| 148 | 401.921573 | 198 | 401.996577 |
| 149 | 401.923073 | 199 | 401.998077 |

# APPENDIX 6

## GOES DATA COLLECTION SYSTEM PASSIVE RECEIVING STATION

### Summary

This project covers the design, development, fabrication, installation and debugging of a passive GOES receiving station that will be located on the north side of the building in Brasilia occupied by the Instituto Nacional de Meteorlogia de Ministerio da Agricultura (INMET). The site would be used with GOES east, located at 75° west longitude and should have the capability of receiving data from at least one but preferably up to five GOES channels, converting the data to engineering units and distributing it to users.

### Receiving subsystem

All GOES DCP data are transmitted from the spacecraft on phase modulated carriers offset from a S-band pilot carrier centered at 1694.450 MHz. The carriers of the self-timed DCP data are offset in 3 KHz increments to the left and those for interrogable DCPs 1.5 KHz to the right. These carriers are PSK modulated with a 100 band Manchester II encoded bit stream. Reception consists of downconverting all DCP carriers to a suitable intermediate frequency band then selecting the desired carrier(s) using a stable band pass filter. Because the spacecraft DCS antennas are electronically de-spun, there have been phase modulation problems.

In considering the antenna system, trade-offs can be made between antenna size and performance, however, the gain provided by a larger antenna can be misleading since the higher gain is realized only when the antenna is aimed directly at the satellite. Since it is preferable to operate the system without constantly re-aiming the antenna, a small antenna may be more satisfactory, especially keeping in mind its lower cost.

### Data handling subsystem

Once the appropriate data stream has been selected, it passes through a demodulator/bit synchronizer which recovers the original encoded waveform and conditions it for further processing.

This demodulator output serves as an input to a mini computer complete with printer that performs the following functions:

1. Compares DCP identification numbers to a file already stored in the computer, accepting only those data for which a match is made.